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OF THE

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TABLE OF CONTENTS.

SECTION I. INSTITUTE ANNOUNCEMENTS.

PAGE
List of Officers, ... iv
Bi-Monthly Bulletin, ... v
Library, ... vi
Membership, ... xi

SECTION II. TECHNICAL PAPERS.

No. 1. Frank Firmstone. An Old Specimen of American Spiegeleisen, . 1
No. 2. Alexander N. Mitinsky. Crushing-Tests of the Diamonds Used in Drilling, ... 5
No. 3. John B. Hastings. Are the Quartz-Veins of Silver Peak, Nevada, the Result of Magmatic Segregation? 9
No. 4. Frederick C. Brown. The Importance of Fine Grinding in the Cyanide Treatment of Some Gold- and Silver-Ores, ... 17

17413

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PAGE

No. 5. EDWARD DE MILLE CAMPBELL. Discussion of the Paper of JAMES GAYLEY, "The Application of Dry-Air Blast to the Manufacture of Iron," 25

No. 6. H. O. HOFMAN. Reply to the Discussion by MR. T. K. ROSE of MR. HOFMAN'S Paper, "The Effect of Silver on the Chlorination and Bromination of Gold," 51

No. 7. M. H. HARRINGTON. The Beard-Mackie Sight-Indicator for the Measurement of Marsh-Gas in Collieries, ... 53

No. 8. R. H. SWEETSER. Discussion of the Paper of H. R. HALL, "The Use of High Percentages of Fine Ore in a Charcoal Blast-Furnace," 63

No. 9. CHARLES E. W. BATESON. The Mojave Mining District of California, ... 65

No. 10. GELASIO CAETANI. Fine Grinding of Ore by Tube-Mills, and Cyaniding at El Oro, Mexico, ... 83

No. 11. JOHN BIRKINBINE. Discussion of the Paper of JAMES GAYLEY, "The Application of Dry-Air Blast to the Manufacture of Iron," and of J. E. JOHNSON, "The Physical Action of the Blast-Furnace," 137

APPENDIX. List of Members, Corrected to November, 1905, . 1 to 159

SECTION I.

INSTITUTE ANNOUNCEMENTS.

This section contains announcements of general interest to the members of the Institute but not always of sufficient permanent value to warrant republication in the volumes of the *Transactions.*

American Institute of Mining Engineers.

(Organized in 1871, and Incorporated in 1905.)

OFFICERS.

For the year ending February, 1906.

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BI-MONTHLY BULLETIN.

For the convenience of persons who desire to file, or otherwise use separately, the technical papers in Section II. of the Bulletin, each of these papers has been paged and wired by itself; the whole collection being held together by a single, heavy wire, upon the removal of which it will fall apart into individual pamphlets, substantially like those formerly issued.

A small stock of separate pamphlets, duplicating the technical papers given in Section II. of this Bulletin, is reserved for those who desire extra copies of any single paper.

All communications concerning the contents of this Bulletin should be addressed to R. W. Raymond, Secretary, 99 John St., New York City (P. O. Box 223; Telephone number 5477 John).

The present issue comprises a List of Members, corrected to November 15, 1905, which can be easily detached for convenient use. Extra pamphlet copies of this list can be obtained by members, postpaid, upon remittance of 50 cents per copy.

LIBRARY.

The following volumes are needed to complete sets in the library:

Berg- und Hüttenmännische Zeitung, volumes i. to xxi., inclusive.

NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS, *Transactions*, volumes xxiii. to xxvi., inclusive.

Stahl und Eisen, Nos. 1, 2, 3 and 4 of vol. i.; Nos. 8, 9, 11 and 12 of vol. ii.; and indexes to vols. i., ii. and iii.

Zeitschrift für Angewandte Chemie, Years i. to xii.; xvi. to xvii.

Giesserei Zeitung, Year i., Nos. 1 to 17, 19–26; Year ii., Nos. 1 to 6, inclusive.

Accessions.

From October 16 to December 15, 1905.

Bureau of Government Laboratories, Philippine Islands.

COPELAND, E. B. *The Polypodiaceae of the Philippine Islands.* 146 p. pl. 8vo. Manila, 1905.

LEWIS, G. N. *Autocatalytic Decomposition of Silver Oxide.* 27 p. pl. 8vo. Manila, 1905.

STRONG, R. P. *Clinical and Pathological Significance of Balantidium Coli.* 77 p. pl. 8vo. Manila, 1905.

Bureau of Mines of Ontario.

ONTARIO BUREAU OF MINES. *The Cobalt-Nickel Arsenides and Silver-Deposits of Temiskaming*, by Willet G. Miller. 66 p. il. pl. map. 8vo. Toronto, 1905.

Chemical and Metallurgical Society of South Africa, Johannesburg.

CHEMICAL AND METALLURGICAL SOCIETY OF SOUTH AFRICA. *Proceedings*, 1902–'03. Vol. iii. 8vo. Johannesburg, 1905.

Professor F. G. O. Doeltz.

Zeitschrift für Angewandte Chemie. Years 1900–'02. 8vo. Berlin, 1900–'02.

Engineering and Mining Journal.

One hundred and sixty-three odd numbers of Periodicals, including seventy-three duplicates.

BECK, DR. RICHARD. *The Nature of Ore-Deposits.* Translated and revised by Walter Harvey Weed. 2 vols. il. map. 8vo. New York, London, 1905.

[SECRETARY'S NOTE.—American mining engineers and students of the theory of ore-deposits as a part of the science of geology will welcome this English version of the already classic treatise of Prof. Beck (*Lehre von den Erzlagerstätten*), the first edition of which, issued in 1900, was followed in 1903 by a second, upon which the present work, issued with his approval, is based.

Prof. Beck's treatise appeared at a critical period, when important additions had recently been made to the literature of the subject with which it dealt, requiring, on the one hand, a just estimate of the new material, and, on the other hand, a logical perception of its relations to the old. Such a discriminating summary his timely book furnished. The frequency and fullness of its quotations from the *Transactions* of this Institute, and its frank recognition of the work of American economic geologists, prove the wide reading and the liberal temper of the distinguished author.

The great merit and usefulness of that treatise, as of this translation of it, consist in its presentation of an intelligent general review, accompanied with such abundant inferences as will enable the student to make further researches for himself. In the present stage of scientific progress, this is all that any one general hand-book can do, and all that any student desires. What we all want is not a vast undigested aggregate of alleged observations and more or less reliable theories, but a summary of reasoned conclusions, and a guide to the examination of their grounds.

Incidentally, this manual gives also brief accounts of the leading mining districts and famous mines of the world, with references to the monographs in which they are more fully described.—R. W. R.]

Geological Survey of Louisiana.

LOUISIANA GEOLOGICAL SURVEY. *Bulletin*, Nos. 1–3. 8vo. Baton Rouge, 1905.

Institution of Mining and Metallurgy, London.

GEIKIE, J. S. *The Occurrence of Gold in Upper Sarawak.* 17 p. il. 8vo.

HOLLOWAY, G. T. *Sieve and Screen Apertures.* 8 p. tab. 8vo.

INSTITUTION OF MINES AND METALLURGY. *Transactions.* Vol. xiv. 8vo. London, 1905.

Institution of Naval Architects, London.

INSTITUTION OF NAVAL ARCHITECTS. *Index to the Transactions* (vols. i–xlvi, 1860–1904). 268 p. 4to. London, 1905.

——— *Transactions.* Vol. xlvii. 2 parts. 4to. London, 1905.

Jeffrey Manufacturing Company.

JEFFREY MANUFACTURING COMPANY. *Catalogue Illustrating Machinery Specially Designed for Handling Coal at the Mines.* 142 p. 8vo. Chicago, 1905. (No. 20.)

Richard Moldenke.

AMERICAN FOUNDRYMEN'S ASSOCIATION. *Transactions,* 1904. 8vo.

Pennsylvania State Library.

PENNSYLVANIA—DEPARTMENT OF MINES. *Report of the Department of Mines of Pennsylvania,* 1904. Part i. 8vo. Harrisburg, 1905.

Richard Pfund.

Engineering Magazine. Vol. i., No. 6. 8vo. New York, 1891.

Heinrich Ries.

RIES, HEINRICH. *Economic Geology of the United States.* xx, 435 p. il. map. 8vo. New York, 1905.

[SECRETARY'S NOTE.—This volume is primarily intended as a text-book for instruction in other colleges; but it constitutes also a highly useful summary for mining engineers already in active practice, and for the increasing number of intelligent citizens who desire to know something of the mineral resources of their country. If such knowledge were more general and more thorough than it is, we should be spared much talk from theorists and demagogues concerning the sources of large fortunes and the imagined injustice of our social order. The increase of our national wealth through the simple discovery and exploitation of new treasure, heretofore unknown, will go far to explain all the phenomena which are so often hastily stigmatized as evidences of corrupt and selfish practices. Indeed, if to the new wealth thus developed by agriculture and mining, we should add that which has been derived from inventions of revolutionary importance and well-nigh immeasurable pecuniary value, not only the great fortunes of the day, but also the notable increase in the comfort and prosperity of our people at large, would be accounted for.

Prof. Ries has built largely upon the basis of the earlier manual of Prof. R. S. Tarr; and his work constitutes an admirable up-to-date presentation of the subject. Perhaps its most valuable portion is that which discusses the non-metallic minerals—a department comparatively neglected in the text-books which deal mainly with the more fascinating theme of ore-deposits. Under the titles, Coal, Petroleum, Natural Gas, Building Stones, Clay, Lime and Cements, Salines, Gypsum, Fertilizers, Abrasions, Water, Soils and Road Materials, a mass of information is given with clearness and discrimination, which cannot easily be found elsewhere so widely comprehensive and so well arranged and explained.—R. W. R.]

C. M. Rolker.

GREAT FINGALL CONSOLIDATED, LIMITED. *Report on Property,* by Charles M. Rolker. 57 p. tab. maps. 4to. London, 1905.

——— *Tabulated Statements.* 116 p. 4to.

Secretary of American Mining Congress.

AMERICAN MINING CONGRESS. *Report of the Proceedings of the Seventh Annual Session of the American Mining Congress*, Portland, Oregon, August 22–27, 1904. 8vo. Denver, 1905.

F. C. Smith.

CHEEVER, B. W. and SMITH, F. C. *Select Methods in Quantitative Analysis, Chiefly Inorganic.* Fourth Edition Revised and Enlarged. Parts i. and ii. 273 p. 8vo. Ann Arbor, 1905.

Société Géologique du Nord, Lille, Belgium.

SOCIÉTÉ GÉOLOGIQUE DU NORD. *Annales.* Vol. xxxiii. 8vo. Lille, 1904.

University of California, Department of Geology, Berkeley.

KNOPF, A. and THELEN, P. *Sketch of the Geology of Mineral King, California.* pp. 227–262. pl. 8vo. Berkeley, 1905.

REID, J. A. *Structure and Genesis of the Comstock Lode.* pp. 177–199. 8vo.

THELEN, PAUL. *Differential Thermal Conductivities of Certain Schists.* pp. 201–226. pl. 8vo.

Dr. Leonard Waldo.

MINET, ADOLPHE. *The Production of Aluminum and its Industrial Use.* Translated, with Additions by Leonard Waldo. 256 p. il. 12mo. New York, 1905.

[SECRETARY'S NOTE.—Metallurgists interested in the aluminum industry will welcome Dr. Waldo's timely translation of the German edition of Adolphe Minet's well-known monograph *Die Gewinnung des Aluminiums und dessen Bedeutung für Handel und Industrie*, published in 1902. This work considers the Chemical method of producing aluminum (Processes based on the reduction by means of sodium ; Processes which do not employ sodium) ; Electrochemical methods of producing aluminum (Electrothermic processes ; Electrolytic processes for the production of aluminum) ; Aluminum industry ; Aluminum and its alloys (Pure aluminum ; Heavy alloys ; Alloys of medium density ; Alloys of various densities ; Light alloys) ; Working of aluminum (Process for soldering aluminum ; Electroplating of aluminum) ; Uses of aluminum ; and Aluminothermy. In the second chapter of the Appendix Dr. Waldo describes the developments of the aluminum industry in recent years, more especially in the United States—a matter which the original work overlooked.—R. W. R.]

T. L. Watson.

VIRGINIA GEOLOGICAL SURVEY. *Lead- and Zinc-Deposits of Virginia*, by Thomas Leonard Watson. 156 p. il. pl. map. 8vo. n. p., 1905.

Miss M. Wilman.

WILMAN, M. *Catalogue of Printed Books, Papers and Maps Relating to the Geology and Mineralogy of South Africa.* pp. 283–467. 8vo. [Cape Town, 1905.]

MEMBERSHIP.

The following list comprises those persons elected as Members or Associates, who duly accepted election during the period from November 1, 1905, to January 1, 1906.

HONORARY MEMBERS.

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Thomas Anthony Wood	Dincan, B. C., Canada.

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George R. Lyman	Minneapolis, Minn.
Major-General Charles Francis Roe	New York, N. Y.
Adolphus James Taylor	Sydney, N. S. W., Australia.

NECROLOGY.

The following list comprises the names of members whose deaths have been reported to the Secretary of the Institute during the year 1905. It is doubtless incomplete, by reason of delay in sending such reports. Members are requested to read it carefully, and to call the attention of the Secretary to any omissions which they may discover.

Date of Election.	Name.	Date of Decease.
1903.	*Adams, Charles C	August 31, 1905.
1898.	**Anderson, John Wesley	May 19, 1905.
1901.	†Barber, William B	May —, 1905.
1900.	*Bennet, T. A	November 22, 1905.
1901.	*Bryan, Luke W	March 26, 1905.
1874.	*Cooper, Edward	February 25, 1905.
1875.	*De Camp, W. S	April 5, 1905.
1889.	*Eldridge, George H	June 29, 1905.
1871.	*Frazier, B. W	January 4, 1905.
1897.	*Guinn, John B	May 19, 1905.
1900.	*Irish, Dana C	April 4, 1905.
Hon.	*Kerl, Dr. Bruno	March 25, 1905.
1899.	†Lee, Harry H	April 21, 1905.
1902.	*Lindsey, William A	February —, 1905.
1884.	*Luther, R. C	March 6, 1905.
1899.	*McLean, Gordon	June 6, 1905.
1902.	*McNamara, Herbert H	January 8, 1905.
1893.	*MacNaughton, James	December 29, 1905.
1886.	*Meyer, A. R	December 1, 1905.
1898.	*Parker, W. J., Jr	July 21, 1905.
1895.	*Philips, Joseph, Jr	October 13, 1905.
1902.	†Ripley, Charles O	September 21, 1905.
1883.	*Schmitz, E. J	April 5, 1905.
1900.	†Seeger, Ludwig	March 10, 1905.
1900.	*Sperry, Jacob J	————————.
1902.	*Stoiber, Gustavus H	August 8, 1905.
1905.	*Study, William L	June 8, 1905.
1900.	*Swan R. M. W	January —, 1905.
1886.	*Terhune, R. H	About January 15, 1905.
1892.	*Thiry, Joseph	September 8, 1905.
1903.	*Tisdale, John N	About November 6, 1905.
1897.	*Totten, Alfred I	July 21, 1905.
1902.	*Virgoe, Walter H	May 18, 1905.
1890.	*Wellman, Charles H	June 22, 1905.

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* Member. † Associate. ** Life Member. †† Life Associate.

SECTION II.

TECHNICAL PAPERS AND DISCUSSIONS.

[The American Institute of Mining Engineers does not assume responsibility for any statement of fact or opinion advanced in its papers or discussions.]

A detailed list of the papers contained in this section is given in the Table of Contents, pages i and ii.

Comments or criticisms upon all papers given in this section, whether private corrections of typographical or other errors or communications for publication as "Discussions," or independent papers on the same or a related subject, are earnestly invited.

SUBJECT TO REVISION.

[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

An Old Specimen of American Spiegeleisen.

BY FRANK FIRMSTONE, EASTON, PA.

(South Bethlehem Meeting, February, 1906.)

THE piece of spiegeleisen, the analysis of which is given below, was collected by my father, together with various other specimens, while he was manager of the Glendon Iron Works. It bears a label stating that it was taken from a building in the town of Newton, New Jersey, erected in 1765 and torn down in 1863. The building belonged, in 1863, to T. N. McCarter, Esq. The label is in the hand-writing of Mr. McCarter, now deceased, well known as a member of the bar of northern New Jersey. The specimen was, no doubt, given by him to my father, with whom he had business in 1863 and 1864. It is now in the metallurgical collection of Lehigh University.

I know nothing further as to the history of the specimen, but there is no reasonable doubt that it was made from ore from the Andover mine, at the old charcoal-furnace which once stood at the village of Andover, about 5 miles south of Newton, on the Sussex railroad. It was probably broken from one end of a bearer over an open fire-place, is about 6 in. wide by 2.5 in. thick, has been cast in open sand and shows the characteristic fracture of spiegeleisen rather low in manganese. One edge has been white-washed.

Analyses of Spiegeleisen Made from Andover Ore.

	I. Per Cent.	II. Per Cent.
Graphite,	0.101	0.005
Combined carbon,	4.529	4.212
Silicon,	0.037	0.294
Manganese,	5.750	3.750
Sulphur,	0.003	0.031
Phosphorus,	0.060	0.072
Iron,	89,440	91,570
	99.920	99.934

I. Spiegeleisen made at Andover (charcoal) furnace not later than 1765.

II. Spiegeleisen made from Andover ore at Phillipsburg, N. J., anthracite-furnace, 185–.

Both analyses were made by Dr. P. H. Shimer.

There is nothing to be seen to-day of the old furnace at the reputed site in the village of Andover; but there is a large cinder-heap there, and I have no doubt, therefore, that this is really where it stood. This cinder-pile is on a small stream, the outlet of a lake south of Andover, and a little east of the railroad. The water runs into the Pequest. Just below the cinder pile is an old stone grist-mill, still in use. The date 1761 is cut on a stone on the northwest corner, about 18 in. under the eaves. This mill, no doubt, was built about the same time as the furnace, a mill being at that period an indispensable adjunct to an iron-works.

Mr. W. R. Ayers, of Andover, who pointed out this inscription to me, and kindly gave me much other information, has in his possession a pig of iron about 2 ft. 10 in. long with the brand "Andover" on it in very well formed letters. It was taken from a house belonging to him, in which it formed a lintel over an open fire-place. The house is said to have been built before the Revolution. This pig, judging by the face, is not spiegeleisen.

Almost all the cinder to be seen on the old dump is gray, and indicates very regular furnace-work. Below are analyses of two pieces which I took from the dump on my first visit to Andover.

Analyses of Cinder from Old Andover Charcoal-Furnace.

	No. 1. Per Cent.	No. 2. Per Cent.
SiO_2, ...	45.29	36.57
Al_2O_3, ...	2.67	5.49
FeO, ...	0.55	1.44
MnO, ...	7.20	4.43
CaO, ...	34.74	41.17
MgO, ...	6.53	8.77
K_2O, ...	0.49	0.33
Na_2O, ...	0.11	0.09
SO_3, ...	0.137 (S, 0.055)	0.191 (S, 0.077)
CO_2, ...	1.59	0.74
Combined water, . . .	0.49	0.40
	99.797	99.621

The last three constituents are, doubtless, due to long weathering.

Sample No. 1 is highly crystalline in fracture; No. 2 is compact and shows no signs of crystallization. Both are of rather unusual composition for charcoal cinders, although No. 1 is not very different from a cinder from Långshyttan (Sweden) given by Åkerman.[1]

I think the spiegeleisen made at the old Andover furnace must have been the first produced on this side of the Atlantic.

The Andover furnace has additional historical interest in that, as appears in Swank's account of it,[2] and the documents there referred to, it was taken into possession by the government in 1778, and run to furnish iron for steel for the War Department, this being the only iron which would "with certainty answer the purpose of making steel."

If the accounts of the Continental War Department have been preserved and are accessible, they would furnish amusing, and perhaps important, details of methods, costs, etc.

The Andover mine, about a mile north of the furnace-site, is described in Kitchell's *Annual Report on the Geological Survey of the State of New Jersey for the Year* 1855 (Trenton, 1856), pp. 149 *et seq.;* and there are further notes in Lesley's *Iron Manufacturer's Guide*, p. 427. The description in Kitchell's report is reprinted in Prof. Geo. C. Cook's account of the mine,[3] with some historical details taken from a letter from Hon. A. S. Hewitt.

In 1848 and 1849 the mine was re-opened by the Trenton Iron Co. (Messrs. Cooper & Hewitt); and much iron was made from the ore in the '50's at the furnaces of that company at Phillipsburg, N. J., at first under the management of Dr. G. G. Palmer, who built the works, and afterwards under his immediate successor, our fellow-member, Mr. J. C. Kent. Much of this iron was spiegeleisen, and large quantities were puddled at the mills of the same company in Trenton, and, no doubt, contributed to the good quality of the "Trenton" rails, which were famous in their day. Through Mr. S. B. Patterson I have procured a small piece of the spiegeleisen made at Phillipsburg, and the analysis (Sample II.) is given above. Unfortunately, the exact date of manufacture is not known.

Mr. Kent informs me that the furnaces worked very well on this ore, and that over 300 tons of iron per furnace per week were sometimes made—which for that day, and with anthracite for fuel, was an enormous output. He also tells me that Mr. Peter Cooper, knowing that the iron had been used for steel in Revolutionary times, had steel made from some of the first iron produced at Phillipsburg and Trenton, and that this steel was worked up into cutlery.

---

[1] *Stahl u. Eisen*, No. 6, 1886, p. 388, table.

[2] *Iron in All Ages*, 2d ed., p. 153.

[3] *Geology of New Jersey*, 1868, p. 640 *et seq.*

The mine was practically exhausted before the successful introduction of the Bessemer process into this country, otherwise spiegeleisen of such good quality must have played an important part in the early history of that manufacture here.

In 1868 Messrs. Cooper & Hewitt sold the Phillipsburg furnaces, the Andover mine-tract, and various other mineral properties and leases in New Jersey, to a joint stock-company, which took the name of Andover Iron Co. In 1901 this company and its belongings passed, by purchase of the stock, into the hands of Mr. Joseph Wharton.

[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

Crushing-Tests of the Diamonds Used in Drilling.

BY PROF. ALEXANDER N. MITINSKY, MINING ACADEMY OF EMPRESS CATHERINE II., ST. PETERSBURG, RUSSIA.

(South Bethlehem Meeting, February, 1906.)

Up to a certain limit, the increase of pressure on the diamond-drill increases the rate of progress in drilling. That limit is set by the resistance of the diamonds to compression; and beyond it, the destruction of the stones will involve an economic loss, both in time and in money. It is, therefore, important to all diamond-drillers to know what is the resistance mentioned.

In Europe, operators usually follow an empirical rule, which directs the maintenance of a pressure, on the area of the bottom of the drilling-tool, of 12 kg. per sq. cm. For the tools in ordinary use, this is equivalent to 1 kg. per sq. mm. of the diamonds set in the tool.

So far as I know, American drillers are using pressures as high as 50 to 60 kg. per sq. cm. of the total area of the drill, and the consumption of diamonds (on Denny's authority, 0.2 carats per meter bored) is greater in America than in Europe. But the reason for this difference may be the comparatively larger size of the diamonds commonly used by American drillers.

With the assistance of my friend, the late S. Woisslaw, who was the pioneer of diamond-drilling in Russia, I selected from his stock a number of black diamonds, which I subjected in my laboratory to compression-tests.

To prepare regular cubes for such tests, as is generally done with other stones, would have been not only costly, but, what is more important, practically useless. I therefore determined, in order to assimilate as nearly as possible the conditions of actual use, to place each sample between a hard plate (corresponding to the rock) and a softer plate (corresponding to the bottom of the tool), into which it would be pressed during the test.

In my first experiment, I placed a diamond between a plate of rolled steel and one of soft bronze, under a very sensitive press, having a diagrammatic recording-apparatus, with a maximum load of 1 metric ton. The diamond endured the pressure of 1 ton, and penetrated into both plates without breaking. The area of its impress in the plates could not be determined with any degree of accuracy by ordinary methods; but by taking photographs, enlarging them, and then measuring them with a planimeter, I found the area of the impression in the bronze plate to be 19.5, and in the steel plate, 17.25 sq. mm. The half-sum of these areas, 18.4 sq. mm., being taken as the area of the diamond submitted to pressure, indicates that, under the pressure of 1 ton, exerted by the press, the diamond resisted 54.3 kg. per sq. mm. without breaking.

In my second experiment, I put a diamond (a very small one) between hard tool-steel and rolled soft steel. It broke under 370 kg., leaving on the mild steel an impression of 9.1 sq. mm., and on the tool-steel one of 3.3 mm., corresponding to breaking-pressure per sq. mm. of 45.5 and 115.6 kg. respectively, or an average strength of 80.6 kg.

Subsequently, I compressed three diamonds successively between two pieces of steel of the tensile strength of from 40 to 50 kg. per sq. mm. After these tests, the diamonds were so firmly held in the plates that it was difficult to remove them. The difference of areas of the impressions in the two plates amounted to 8 per cent. The results of the test were:

Experiment No.	Total Load. Kg.	Half-sum of Areas. Sq. mm.	Breaking Strength. Kg. per sq. mm.
3	620	8.0	77.5
4	993	17.5	56.7
5	768	11.0	70.0
		Average, .	. 68.0

In view of these tests, I think that the pressure on drilling-tools can safely be made heavier, with corresponding gain in speed of drilling. American operators are already in advance of Europeans, but could go even further in this direction.

In Russia, the makers of diamond-tools frequently use a patented method of inserting the stones, which consists in enveloping the diamond in a piece of thin steel; putting it, together with some welding-powder, under pressure in the tool which had been heated to incandescence; hammering, and then cooling very quickly.

After my tests had been made, Mr. Woisslaw ordered his workmen to leave the danger of breakage out of consideration, and to put upon the diamonds the highest pressure attainable with their machinery. The results were very good. By this method tools can be obtained which will run safely at a peripheral velocity of 25 m. per second.

SUBJECT TO REVISION.

[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

Are the Quartz-Veins of Silver Peak, Nevada, the Result of Magmatic Segregation?

BY JOHN B. HASTINGS, DENVER, COLORADO.

(British Columbia Meeting, July, 1905.)

CHIEF among the varied problems facing the mine-manager is that of vein-structure and origin, which is highly important as a guide to successful discovery and development. If metalliferous deposits can be traced to the intrusion of waters along definite lines, then is there something tangible for him to study. But when he is told by a geologist that metalliferous deposits are due to some other cause, like magmatic differentiation, while not perhaps discouraged, he is impressed with a vague sense of new worlds to be conquered.

In 1897, while manager of the War Eagle mine at Rossland, B. C., where, previously, the ore-bodies had not been supposed to occur as veins, I suggested to visiting members of the Canadian Geological Survey that, perhaps, the structure of the pyrrhotite-bodies of that mine, which had been proved to occur along well-defined fractures, might throw some light on the similar deposits of Sudbury, then held to be basic aggregations from the original magma. Later investigation has at least provoked discussion of this last deduction, questioning its correctness and suggesting that, perhaps, the deposits are actual veins.

The following extract from a paper by J. E. Spurr[1] is quoted, because it sets forth Mr. Spurr's theory of the quartz-occurrences of the Silver Peak mines, which will be discussed in this article. It also graphically describes the attendant geological features.

> "The Drinkwater group of mines, which is the most important part of the Blair gold properties, and which has produced practically all of the million dollars' worth of ore, as above stated, may be taken as typical of the gold-veins which, though widespread and numerous, show a wonderful similarity of character. On the surface two adjacent veins outcrop, the Crowning Glory and the

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[1] Ore Deposits of Silver Peak Quadrangle, *Bulletin No.* 225, *U. S. Geological Survey*.

Drinkwater, the former the larger, the latter containing the greater quantity of good ore. The quality of the ore still left standing (only the richer portions having been removed for milling) has been more or less carefully determined a number of times. . . . .

"Geologically, the veins of the Blair mine are interesting. Properly speaking, they are hardly veins, but flattened lenses of quartz occurring in a definite zone 100 ft. or more in thickness. The lenses wedge out and disappear both horizontally and vertically, and their place is taken by overlapping lenses. The wall-rock is a schist, derived chiefly from the metamorphism of an original limy shale or limestone. Frequently, also, the wall-rock is a very siliceous granitic rock (alaskite), made up essentially of quartz and feldspar. This alaskite occurs in the schist in lenses similar to the quartz. There is, moreover, every transition between the alaskite and the quartz; and the schist has been, so to speak, saturated with this siliceous material, which forms seams and thin lenses in it. The auriferous quartz-lenses in the mine in many places run laterally into quartz-feldspar rock (alaskite). As a rule, the values grow insignificant with the coming-in of the feldspar, but occasionally high values may still be found.

"The general conclusion is, that here a series of fissile shales and thin-bedded limestones has been invaded by a very siliceous granitic intrusion which has metamorphosed the sediments to schists. *The quartz has plainly the same origin and nature as the alaskite, both being siliceous phases of a granitic magma* [the italics are mine.—J. B. H.]. The gold in the quartz is usually free, sometimes associated with scattered galena [and pyrite.—J. B. H.]. Greenstone or diorite dikes cut the veins or follow along them, but are of later age. Along the dikes there has been water-circulation, resulting sometimes in impoverishment, sometimes in relative concentration of the original values.

"This zone of veins outcrops for a mile along the mountain side. At one point, some distance below the vein-zone, free gold in fresh alaskite was found.

"In the main, the other gold-mines or prospects of the district have exactly the same geological relations."

At my first examination of the Blair properties, in December, 1900, having, to guide me, the thorough reports of James D. Hague and George W. Maynard, I spent only one day on the hill; at my second visit, in May, 1905, I was half a day at the Blair mines and three days at the adjoining Valcalde group.

The mines are on ridges north from the Silver Peak, not on that mountain proper, which rises 1,500 ft. higher (to 9,000 feet). It is volcanic; the various flows extend for miles easterly, and the successive stages of its growth are marked. It is reported that there is on the top an oblong depression, 2,000 ft. long, filled with water from melting snow.

Many mining engineers, who have examined veins in schists, will recognize the accuracy of Mr. Spurr's description of the formation in lenses, the disappearance both horizontally and vertically, and the replacement by overlapping ones. They also have sampled veins in granite which have passed gradually from quartz to granite, and have noted the usual disappearance of metallic values with the appearance of the feldspars.

At my first visit, having no idea of the quartz ever being considered a phase of the granite, and at my last, being busily engaged with the economic features of the Valcalde group, I did not closely study the occurrence of alaskite within the granitic area; but it was seen in proximity to the great cuts on the Drinkwater mine, especially on the northeasterly or hanging-wall; and large masses in front of the vein presented a gneissoid appearance and were extremely silicified. In the southwesterly or foot-wall of the veins, the rock appeared to be normal granite, with muscovite and biotite; occasionally it looked as if the muscovite might be an alteration-product, but usually the rock was in normal condition, except that in all the pieces found the biotites were in the last stages of alteration. Alaskite was observed in other places among the mines, and away from the veins; and it seemed as if the absence of the micas were due, in part, to their elimination near the veins and other zones of movement, and sometimes to differentiation of the magma. The lenses in the schists are usually alaskite, but as most of these areas have been subjected to solfatarism, I could not decide whether the absence of the mica was primary or secondary. At the Drinkwater group the outer area bordering the limy shales is alaskite, and at the Valcalde group the granite adjoins the same rocks. The whole granitic mass of the mines is one magma. There has been fissuring of the normal granite, attended with injection of dikes and formation of veins, but sometimes without either. The micas adjacent to the movement have been more or less destroyed (as in the Boise basin) and aplite has been formed; and again aplite occurs as a phase of the original magma.

The whole granitic area has been subjected to slight fracturing, the cracks cemented with the usual quartz as seen in granite, sometimes auriferous, usually not. These quartz seams are white and solid, glassy, chalcedonic or crystalline, and contain cavities, which are sometimes filled in with chalcedonic quartz.

Mr. Spurr speaks of finding gold in fresh alaskite-pegmatite country-rock below the veins. I found coarse gold at a point in the gulch below the Frank No. 2 mine, possibly on the Columbus, and south of the New York, from 200 to 500 ft. from the veins. The gulch follows a line of movement occupied more or less by a greenstone dike, from 6 to 8 in. wide, dipping flatly to the west. At this particular place the dike is not seen. Along the denuded foot-wall the alaskite is unaltered, except for small deposits of quartz and iron in masses an inch or so in diameter where the gold occurred. A small quartz-vein 6 in. or less wide, more or less accompanying the dike, which is also the foot-wall. This vein outcrops at the bottom of the gulch, and the quartz is clearly different from that in the alaskite. Its strike is NE. and dip NW.; the Blair veins strike NW. and dip NE.; and the Valcalde veins in this neighborhood strike north and dip east.

The following characteristics of the Blair veins were noted: Beginning at the workings farthest south, a 50-ft. tunnel is run in the foot-wall, and two cross-cuts made to the vein; the first one is 20 ft. in the solid white vein-quartz, and not through it; the quartz comes in on well-defined fissuring, course N. 30° W., with regular dip 20° NE. The second cross-cut just enters, at the roof, the same white quartz; there is strong fissuring on the contact; the course is more westerly and the dip is the same as in No. 1. The foot-wall is alaskite, containing a few quartz seams; the vein, as specified, is hard white quartz, separated from the foot-wall by uniform and distinct fissuring. The workings on the south side of the gulch expose the vein with the same quartz and the same flat dip, which follows a well-defined fissuring of the alaskite, and a thin greenstone dike, also fissured. A projected cross-section, showing the uniform dip of the Crowning Glory and Drinkwater veins for 1,000 ft. in depth, is given in Fig. 1.

The main Blair deposits, as Mr. Spurr says, occur in two separate veins; and it may be added that these are parallel and 100 ft. apart.

This outcrop of sheared country-rock and quartz, from 75 to 100 ft. wide, striking about N. 35° W., and dipping from 15° to 50° NE., can be traced for 6,000 ft. across a deep gulch, from the Crowning Glory to the New York. Throughout the whole distance, it is attended with fissuring. At the New York there is a belt of the limey shale, with possibly a fissured dike which the vein follows, being always parallel to the fissuring. The quartz outcrop is very prominent for 500 ft. over the New York hill, and extends some distance beyond. The belt of foreign rock (limey shale, etc.), included in the granite, is about 100 ft. wide, but is local; another inclusion joins it on the north, more evidently the limey shale country-rock; here both the shale and granite are sheared, but more nearly north and south than at the vein, and with some silicification. Alongside the vein the granite is not sheared on the New York (as it is further south),—as if there had been enough of the shale to take up the movement.

There are, perhaps, three ages of greenstone dikes,—a diorite quite recent, running NW–SE.; a greenstone later than the veins and sometimes faulting them; and a greenstone older than the veins, which, to a great extent, the latter have followed.

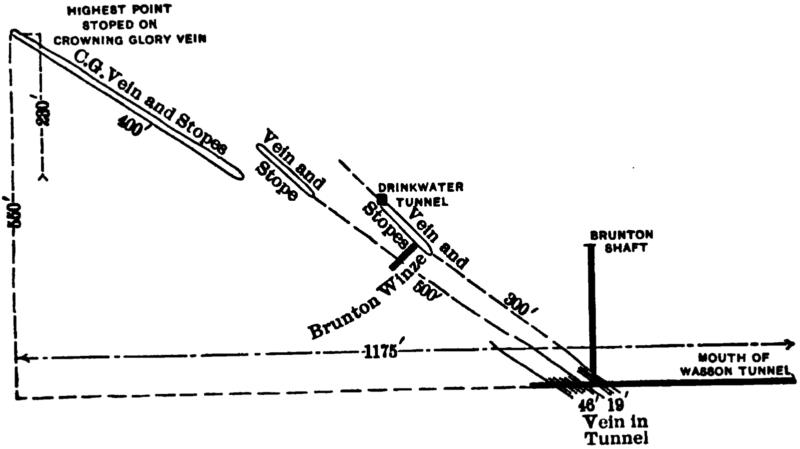

FIG. 1.—PROJECTED CROSS-SECTION OF CROWNING GLORY AND DRINKWATER VEINS.

Mr. Spurr thinks that all the dikes are later than the veins; but the dikes followed by the veins sometimes enclose them, and the quartz is not sheared or broken, while the dike, especially that portion occupied by the vein, is sheared to schistosity. The quartz, both in the dikes and granite, is usually remarkably clean. Distinct silicification of the dikes is seen, which, however, might be secondary.

The Sentinel mine, on the divide between the New York and Drinkwater, is in the limey shale. The only ore-body and occurrence of quartz of consequence is at the open cut alongside the road. This lens is about 30 ft. long, 20 ft. at the widest, strikes N. 20° W., and dips from 20° to 25° E., conformably with the schists. It is near the granite contact. The fissuring differs from that of the Blair mines, and agrees with the regular foliation of the limey shales; it continues down hill to the north, and is accentuated by lenticular streaks of alaskite intrusions. There has evidently been solfataric action along it, resulting in alteration on a small scale of the schists, and sometimes of the alaskite, and the formation of compact, crystalline and chalcedonic seams of quartz. On the whole, the silicification seems to have affected the schists more than the alaskite.

The Valcalde group, adjoining the Blair, exhibits much narrower veins. It comprises in one vein-system the Columbus, Lincoln, Frank No. 2, Washington and Porto, to which might be added the Lucky Sam, owned by other parties. It seems as if all these claims were on one vein. At least, their characteristics are so uniform, and the portions developed hitherto occupy such relative positions, that they may be considered as belonging together. The vein-fissuring and deposition of quartz has followed a pre-existing flat dike, sometimes horizontal, and again dipping as much as 15° easterly or westerly; the dike as seen is from a few inches to 5 ft. thick, and the quartz from a few inches to 6 feet. The dike is distinctly sheared, as is also the granite near the contact, and, in some places, for a foot or two away, the quartz is not broken in the least. The quartz, which is sometimes lenticular in the sheared dike, also occurs in continuous streaks several feet wide within it and also on top of it, with the granite for a distinct hanging-wall. In some places the dike is not seen at all, the quartz occurring as a regular streak in the granite, from 4 to 6 ft. wide, with a remarkably smooth and well-defined hanging-wall; the footwall is not exposed.

This flat fissure, extending from the New York 2,000 ft. southerly, outcrops along both sides of a north-and-south gulch (the central portion having been eroded away), and terminates, so far as known, in the basin at the head of it. Laterally, it may be 1,500 ft. wide; this width is only indicated by the Porto mine. It has been disturbed by north-and-south movements, with and without dikes.

The area is either granite or alaskite, the latter in small patches. The quartz is entirely similar to that of the Blair mines, carrying a little galena and iron sulphides in the best ore.

The Soda mine lies south of the flat vein above described. The vein strikes north and dips 50° westerly. The hard, white vein-quartz is similar to that of the other mines, the best having galena and pyrite. At the working farthest south it is found on the hanging-wall of a lenticular mass of an alaskite dike in limey shale. About 30 in. of the alaskite has been silicified. The east or hanging-wall of the quartz is limey shale and a greenstone dike, the relations of which could not be ascertained. The wall is fissured parallel to the vein. The foot-wall is alaskite; and the quartz merges into it. The alaskite lens, as developed, is 25 ft. long, 10 ft. wide at the middle, and of unknown extent, the northern half only being exposed. Beyond this northern half no more alaskite is found; but the vein, composed of quartz stringers and lenses parallel to the foliation of the schists, has been developed, with a width of from 6 to 10 ft., for 300 ft. further.

The Salisbury mine is in granite, a quarter of a mile from the end of the flat vein. It strikes N. 18° E. and dips 55° easterly. The foot-wall is well defined by 2 ft. of strong fissuring, with a small dike. The vein is 40 in. wide and merges into the granite, giving no defined hanging-wall; but the width of the vein, developed for 55 feet, is uniform. It is cut off on the strike by a NW. fault and dike, dipping northeasterly, which carries quartz without values, as the result of a secondary silicification, and parallel to the movement. The vein-quartz is, like those of the other mines, hard and white, with galena and pyrite.

The Paris mine has about the same character as the Soda, but without an alaskite dike; the enclosing walls are schists, within a granite area; the veins are lenticular and small, from 2 to 4 ft. wide, and contains the same white quartz, with galena and pyrite in the best ore. The course is north and south, and the dip 35° east.

A few specimens from the Valcalde group exhibited: (1) wire gold in soft crystalline quartz (called "decomposed" by the miners); (2) crystalline gold in a dog-tooth quartz lining of a cavity, which was afterwards filled with chalcedony; (3) sheets of gold from cracks in chalcedony; and (4) particles of gold in the richer ordinary vein-quartz, freed by oxidation of the sulphides.

From the above it appears to me: (1) That this district presents bodies of quartz of uniform type, following a well-defined fracturing with regular course and dip, each great fissure having its own direction, varying from NW. in the Blair mines to N. 18° E. in the Salisbury mine, and a dip from horizontal to 15° westerly and 55° easterly, the easterly dip prevailing.

(2) That the values are in the quartz, which is confined to narrow lateral limits, having well-defined walls, which may be granite, schist, or, in a subsidiary way, greenstone dikes. The passing of the quartz into the granite occurs in the usual manner of veins in a granitoid rock; and the relative amount of accompanying silicified or mineralized granite is not more than usual.

(3) Consequently, that the veins are not siliceous segregations from the granite, but have been formed in the usual manner by ascending waters along lines of fracturing.

SUBJECT TO REVISION.

[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

The Importance of Fine-Grinding in the Cyanide-Treatment of Gold- and Silver-Ores.

BY FREDERICK C. BROWN, MANAGER KOMATA REEFS G. M. CO., LTD., AUCKLAND, N. ZEALAND.

(British Columbia Meeting, July, 1905.)

THE practice of fine-grinding is now being so successfully carried on in some fields, notably in West Australia, and its advisability has been so frequently pointed out[1] that the matter in this paper is not put forward as being new; its chief object being to call attention to the importance of fine-grinding in the treatment of comparatively low-grade ores.

I have been engaged during the last five years in the cyanide-treatment of ores in the Ohinemuri district (North Island), New Zealand, and I consider that, in the near future, extremely fine-grinding (almost sliming) will become a very important feature of the milling-methods in this field, since it seems absolutely necessary to reduce the most of ores to a very fine state of division if a high extraction is to be obtained; and, in most cases, the extra percentage of saving will leave a good margin above the increased cost of treatment due both to the fine-grinding and to the interest on the capital spent for the grinding-machinery.

The average ore of the Ohinemuri field is composed of a quartz-gangue with some calcite, carrying the gold-value in the form of an alloy of gold and silver in about equal proportions, and the silver-value in the form of mixed sulphides of silver, usually associated with a considerable amount of iron pyrites. In the upper levels, the ores are decomposed and carry large quantities of black manganese oxide and some iron oxide, but, as depth is reached, the decomposed ore gives place to sulphides and, in some mines, rhodonite, manganese silicate, is present in fairly large quantities. The average value of the ore, received at the mills, ranges from £2 ($10) to £3 ($15) per long ton, the proportion, by weight, of silver to gold being from 8 to 10 of silver to one of gold.

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[1] Bosqui, F. J., *Trans.*, xxxiv., 715, Liberty Bell Mine, Colo.; Christy, S. B., The Cyaniding of Gold-Bearing Sulphurets, *California Miners' Association* (1903).

The usual milling-practice is,—1, fairly fine-crushing in stamp-batteries, using wire screens that range from 30 to 40 holes to the linear inch; 2, amalgamation over copper-plates; 3, separation of the slimes from the sands by hydraulic classification; 4, concentration of the sands by means of rubber-belt vanners or Wilfley tables; 5, cyaniding the sands by the percolation-method (in some mills a double treatment is adopted); and 6, cyaniding the slimes by agitation combined with filter-pressing.

A percentage varying from 10 to 60 is saved by amalgamation, and some ores yield a fair percentage of their value by concentration; but in every case the treatment of the sands and slimes by cyaniding is of the utmost importance, this being the final process to which the ore is subjected, and any values remaining in the tailings thus being lost.

My experience has shown that the average loss of undissolved gold and silver in the slimes is small, but in some mills using the decantation-process, a very considerable loss takes place in the final solution carried away with the slimes which are discharged after the treatment. This loss in the slimes could be obviated by the use of a filter-press, but the necessary plant is very expensive to install, and unless a mine has assured large ore-reserves, it is sometimes risky to expend the capital. The "Moore" or vacuum-process of filtration is now giving encouraging results in the Ohinemuri district, and since the cost of installation of the plant is not excessive, the process might play an important part in the treatment of slimes. A weak feature of the Moore process, however, seems to be that the highest pressure that can be used is comparatively low, say from 11 to 13 lb. to the square inch, which means that a thin cake will be formed in the treatment of very clayey slimes. To overcome this objection a large filtering-area is used which makes the plant somewhat cumbersome. A cheap and efficient system of filtration is greatly needed, and it is quite likely, that, before long, satisfactory results will be forthcoming from the many investigators now working on this problem.

The loss of gold and silver in the sands that are invariably treated by the percolation-method is very considerable. The value of the tailings discharged by the different mills range from 5s. to 10s. ($1.25 to $2.50) per long ton, the proportion of gold being 3s. 9d. to 8s. (95c. to $2) and of silver 1s. 3d. to 2s. (30c. to 50c.). There are two chief reasons to account for these losses:—first, the particles of sand being too coarse to admit of the cyanide solution attacking the enclosed bullion; and second, the incomplete treatment and washing received in the percolation-method. The following grading-tests will show how the coarse particles retain the values. The samples, shown in Table I., were taken from the sand-vats after treatment at the Komata Reefs mine:

TABLE I.—*Values of Classified Sands Taken from Vats After Treatment.*

Size of Grain.	From One Vat.	Average of Five Vats.
Remaining		
On 40-mesh	**30s. ($7.50)**	**15s. 7d. ($3.85)**
On 60-mesh	**19s. 6d. ($2.80)**	**15s. ($3.75)**
On 80-mesh	**8s. ($2.00)**	**7s. 9d. ($1.90)**
On 100-mesh	**3s. 4d. (80c.)**	**5s. 4d. ($1.35)**
On 150-mesh		**4s. ($1.00)**
On 200-mesh		**2s. 6d. (60c.)**
Through 200-mesh		**2s. 6d. (60c.)**

A sample of this ore, crushed and passed through a 35-mesh wire screen, was of the following mechanical composition:

On............	40-Mesh.	60-Mesh.	100-Mesh.	150-Mesh.	200-Mesh.	Through 200-Mesh.
	Per Cent. 3	Per Cent. 10.6	Per Cent. 21.5	Per Cent. 11.9	Per Cent. 9.3	Per Cent. 43.7

An average sample taken from several miles of the bed of a river into which some of the large mills discharge their tailings had a value before re-treatment of 20s. 6d. ($4.95) per ton; its mechanical composition being:

On............	30-Mesh.	60-Mesh.	90-Mesh.	100-Mesh.	150-Mesh.	Through 150-Mesh.
	Per Cent. 1.6	Per Cent. 20.0	Per Cent. 36.2	Per Cent. 21.4	Per Cent. 5.4	Per Cent. 7.4

The sand was ground in the laboratory so that 74.6 per cent. passed a 200-mesh screen and was then carefully treated with

ent. of KCN. until tests showed
ould be dissolved. The results,
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t losses occur by the percolation-
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e mills of a "double treatment"
first treated (obviously incom-
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or even more, treatments would
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screen, followed by amalgama-

the resultant pulp with compara-
accompanied with a large and
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hich have been liberated by the

nd clarification of the gold-bear-
filtration, or by a combination

4. *Precipitation.*—Precipitation of gold and silver from the solutions by zinc shavings, zinc dust or other suitable method.

1. *Grinding.*—The fine-grinding can be accomplished economically in what are known as tube-mills, which are simply lined wrought-steel cylinders about 4 ft. in diameter, and from 16 to 20 ft. long, supported on end-trunnion bearings, and half filled with small rounded flint pebbles (about the size of a hen's egg). These machines are run at a speed ranging from 32 to 27 rev. per min., and the crushed ore from the battery, after the separation of the slimes, is fed in at one end of the machine and discharged at the other end into a hydraulic classifier. From the classifier, that portion of the pulp which is fine enough overflows and goes to the treatment-plant, the coarse particles being discharged at the bottom of the classifier into an elevator, and returned to the feed-end of the tube-mill for re-grinding. These machines have long since passed the experimental stage and are used advantageously in West Australia; they are also being installed at several mills in South Africa, Mexico and New Zealand.

2. *Agitation.*—The agitation of large quantities of very fine sand, under conditions suitable for economical and efficient treatment, has, until now, not been by any means a simple matter; but I have recently perfected an apparatus which fills the following necessary requirements—low cost of installation; no wearing parts; simple and easy in operation; and perfect agitation and aëration of the charge.

The apparatus consists of a tall vat of comparatively small diameter having a cone-shaped bottom, in the center of which is fitted an air-lift pump, the cone being fitted with an arrangement of jets for "softening" the charge at the commencement of the agitation. The sand and solution at the bottom of the tank are continuously lifted and discharged at the top of the tank, and as such fine material has not a great tendency to settle, this circulating-action can be carried on indefinitely with the expenditure of very little power. The conditions for cyanide treatment are perfect, since every particle of sand and slime is constantly coming into contact with the solution and air as it enters the bottom of the air-lift column. Tanks large enough to treat charges of 50 tons are now in successful operation, and larger ones can be built which can handle 100 tons or more at a charge.

3. *Separation.*—The separation of the gold-bearing solution from the pulp can be accomplished by natural settlement and decantation, but this method, especially with some ores, is very slow and requires a large plant; hence, in the case of a mine with a fair length of life before it, some sort of filtration-plant should be used. If circulating-vats, as described above under "agitation," be employed, a combination of natural settlement and filtration could be adopted, since very fine sand settles fairly rapidly after agitation in tall vats, and a large percentage of the slimes is carried down with the sand. Therefore, if, after each agitation, a comparatively short time be allowed for settlement, the supernatent solution, together with the slimes, can be decanted off and passed through a filter-press. By this arrangement a very small filter-press plant would be required, and as the washing of a charge in these vats is simple, a very high percentage of the gold-bearing solution can be recovered at a small cost.

The advantages arising from the system of very fine-grinding outlined above, compared with coarser crushing, are threefold, viz.:—

The dissolving of the gold and silver in the ore takes less time; weaker cyanide solutions can be used; and a better extraction can be obtained.

Treatment of Concentrates.

Concentration has not been included after the grinding treatment, but it is quite likely to be used in those special cases, where an ore carries minerals which cannot be successfully treated by the cyanide process and the elimination of which is necessary to the successful subsequent treatment of the tailings. With ores, however, that yield concentrates which can be successfully treated by the cyanide process (provided they are very finely ground, sometimes even "sliming"), it is probable that the suggested very fine-grinding would reduce the mineral particles of the ore, which are considerably softer than the sand particles, to such a fine state that their values would be extracted by the agitation-system above described. Resulting from many experiments in treating concentrates by the cyanide treatment, I have found that the chief points to be observed are:—

1. The concentrates must not be allowed to become decomposed by being left exposed to the air.

2. Exceedingly fine-grinding is necessary in most cases, and usually the concentrates must be reduced to slimes.

3. Agitation must provide for a good supply of air.

4. Weak cyanide solution will give a good extraction, provided the grinding is fine enough. Since all the above conditions would be obtained by treating the mineral particles, i.e., the concentrates, together with the sand, it would seem as if the special operation of concentration could be dispensed with in some cases; which would mean a great saving in the cost of plant and in its operating expenses.

SUBJECT TO REVISION.

[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

The Application of Dry-Air Blast to the Manufacture of Iron.

A Discussion of the Paper by Mr. James Gayley, read at the Lake Superior Meeting, September, 1904.

BY EDWARD DE MILLE CAMPBELL, ANN ARBOR, MICH.

(Bethlehem Meeting, February, 1906.)

In the discussion of Mr. Gayley's paper on The Application of Dry-Air Blast to Manufacture of Iron,[1] most of the authors have attempted to explain the remarkable results solely on theoretical grounds.

As Mr. E. Windsor Richards has explained, Mr. Dawson showed more than one hundred years ago that blast-furnaces are influenced by variation in the amount of moisture in the air, more fuel, as a rule, being required in summer than in winter. This fact has been a matter of general knowledge to blast-furnace men since Dawson's time, but they do not seem to have appreciated the extreme sensitiveness of a blast-furnace to variations in atmospheric moisture, until Mr. Gayley demonstrated the remarkable improvement which can be brought about by reducing the amount of water carried in by the blast to a small and practically constant amount.

Dr. Raymond seems to be the only one of those who have contributed to the discussion of Mr. Gayley's paper who appreciates the underlying cause of the great value of Mr. Gayley's invention. The great economy in operation is not due to the saving of energy required for dissociation of water in the blast, which it has been shown by others does not exceed 3 or 4 per cent. of the total energy evolved by the fuel, but is due to uniformity of conditions in the hearth, which permits a uniform temperature to be maintained in that part of the furnace. That the great value of dry air is principally due to the elimination of the daily hygrometric variations may be clearly seen from a study of the observations made by me 16 or 17 years ago, while I was chemist for the Dayton Coal & Iron Co., of Dayton, Tenn.

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[1] *Trans.*, xxxv., pp. 746 and 1022.

Before going south, I had held a similar position with the Sharon Iron Co. at Sharon, Pa. One of the first things I noticed on going to the Dayton furnace, which was so much further south than the one at Sharon, was that the southern furnaces at that time apparently had much more difficulty in running uniformly, especially in the winter months, than did the furnaces which were located further north. After watching the furnaces carefully for some time, I noticed that the furnaces usually took more charges during the night-shift than during the day. I also noticed that on several occasions, when there was a marked change in the weather, the furnace seemed to be influenced by the change. The only cause I could see for the furnace driving faster at night than during the day time was that at night there was apt to be a heavy precipitation of dew, with consequent diminution in the amount of moisture blown into the furnace. The effect of this was usually manifest about 9 or 10 p.m., when there was a marked increase in the rate of driving, which was normally maintained until about the same hour in the morning; that is, the furnace ordinarily responded to the change in the amount of moisture within about 4 or 5 hr. after the change had taken place. After observing the furnace for some months, I became so impressed with the sensitiveness of the blast-furnace to atmospheric changes, that I decided to make a systematic set of observations to determine to what extent these changes affected the operation of the furnace.

To this end an ordinary hygrometer, consisting of a dry-bulb thermometer and a second thermometer, the bulb of which was wrapped in lamp-wicking dipping in water, was constructed. This hygrometer was placed in the stock-house, where there was a free circulation of air, but protected from direct drafts, which would cause excessive evaporation from the wet bulb. From the difference in the reading of the dry-bulb and wet-bulb thermometers, the dew-point (the temperature at which the air would be saturated with moisture) was determined. The dew-point having been determined, the amount of moisture per cubic foot of air was found from physical tables, and the figures so found were used as a basis for calculating the amount of coke required to dissociate the water carried in by the blast. Four readings per day were made, at 5 a.m., 12 m., 5 p.m. and midnight. At the time the readings were taken to determine the dew-point, the number of revolutions of the blowing-engines was also recorded.

From the furnace-books, the number of tons of each grade of iron produced daily was taken, as well as the number of pounds of ore charged into the furnace for each unit weight of fuel.

In order to determine the amount of coke required per day, for the decomposition of the moisture introduced by the blast, the following assumptions were made: (1) that the blast was actually on 23 out of 24 hr., a loss of 1 hr. being allowed for the time during which the blast was off for flushing the cinder or casting the iron; (2) on account of the inefficiency of the blowing-engines and leaks in the hot-blast stoves, mains, etc., that 60 per cent. only of the piston-displacement actually entered the furnace; (3) that $\frac{9}{10}$ of the carbon of the coke reached the neighborhood of the tuyeres, where the heat developed by its combustion to carbon monoxide was available for dissociating the water vapor.

The coke we were required to use contained an average of 21 per cent. of ash and about 75 per cent. of carbon. I selected the figures, 23 hr.—60 per cent. piston-displacement, and 90 per cent. of the carbon of the coke reaching the tuyeres—as conservative figures. If the blast were on more than 2 hr.; or more than 60 per cent. of the piston-displacement entered the furnace; or less than 90 per cent. of the carbon of the coke reached the tuyeres;—the figure showing the amount of coke required for the decomposition of the moisture would be correspondingly increased.

The term "grade-heat" was one invented in order to enable the temperature of the furnace, so far as it was indicated by the kind of iron being made, to be expressed in figures and recorded graphically. At the time these notes were made we had no reliable figures showing the temperature existing in the lower part of the blast-furnace. Also, at this same time, the iron was graded by fracture as follows, the grades being arranged according to the temperature of the furnace at the time the iron was produced,—white, mottled, gray forge, No. 3

foundry, No. 2 foundry, No. 1 foundry, No. 1 soft, No. 2 soft, and silver gray or glazed iron. Since the furnace was usually worked on foundry iron, a grade-heat of 1.00 was empirically adopted as representing the temperature existing in the furnace at the time No. 1 foundry iron was being produced. If the furnace cooled off sufficiently to produce No. 2 foundry iron, the grade-heat, 0.98, was adopted; similarly, 0.96 represented No. 3 foundry iron, 0.93 gray forge, 0.90 mottled and 0.88 was the grade-heat employed when the furnace was cold enough to produce white iron. On the other hand, when the furnace was hotter than was necessary to produce No. 1 foundry iron, a grade-heat of 1.02 was employed to indicate No. 1 soft iron, and 1.03 to indicate No. 2 soft; and if the furnace became hot enough to produce silver gray or glazed iron, this was indicated by a grade-heat of 1.05. While these grade-heats probably do not express the exact ratios of the temperature existing in a blast-furnace at the time the different grades of iron are being produced, they do represent the relative temperature, and afford a means of expressing, in figures, the conditions of a blast-furnace. In order to determine the grade-heat for the blast-furnace for any given day, resort was made to the daily report of the iron grades. From this report the number of tons of each grade of iron was obtained, and these amounts were each multiplied by the proper grade-heat, and the sum of these products was divided by the total number of tons produced. For example, if the furnace made 105 tons in a day, consisting of 40 tons of No. 2 foundry, 30 tons of No. 3 foundry, and 35 tons of gray forge, the mean grade-heat would be found as follows:

40 x 0.98,	39.2
30 x 0.96,	28.8
35 x 0.93,	32.55
	100.55

100.55 ÷ 105 = 0.957, the mean grade-heat of the day.

Daily observations were made on the two blast-furnaces of the company from July, 1888, to August, 1890, inclusive, at which latter time I resigned my position to accept the chair of Metallurgy and Analytical Chemisty at the University of Michigan. The result of all these observations were plotted in curves which showed the dew-point, yield of iron per day, the grade-heat and the burden of ore per buggy.

From the original curves, extending over a period of 26 months, which have been kindly lent to me by Mr. W. J. Isaacson (Managing Director of the Dayton Coal & Iron Co.), I have selected 16 typical instances showing the influence of variations in the dew-point on the working of the furnace. The results of these variations are given in Table I., and the data of all the Sections of this table are shown graphically in Figs. 1 to 16.

A study of these curves revealed some exceedingly interesting relations,—especially the sensitiveness of a well-burdened furnace to atmospheric changes. In studying these curves, it must be borne in mind that the variations in atmospheric moisture are not the only irregularities in the material entering the furnace, because the solid material—coke, iron-ore and limestone—are liable to vary from day to day. The company operated furnaces No. 1 and No. 2, which were apparently alike in size (75 ft. high, 18 ft. bosh, 9 ft. hearth), each having eight 6-in. tuyeres. No. 1 furnace was considerably further from the engine-house than was No. 2, which seemed to be about the only difference in the furnaces, yet No. 1 would never average as large a yield of iron, nor would it carry as heavy an ore-burden, as would No. 2. A study of the curves show that while No. 1 furnace was in general affected by atmospheric changes, like No. 2, the extent of the changes was not usually as strongly marked as in the latter furnace. If a furnace is carrying a full burden of ore, the heat being well concentrated in the hearth, with a cool top and the dew-point rises—that is, the amount of moisture introduced at the tuyeres is increased—the effect of this begins to show within 5 or 6 hr., either through a falling-off in the grade-heat alone, or in a cooling-off of the furnace accompanied by slower driving. On the other hand, if a furnace is running normally, with the heat well down in the hearth, with the top cool, and there is a fall in the dew-point, the effect is first shown by a rise in the grade-heat and an increase in the rate of driving,—that is, an increase in the output of iron. If the dew-point remains persistently low, and the ore-burden is not increased, the effect is frequently to raise the width of the fusion-zone, after two, three or sometimes four days, the grade-heat often falling-off somewhat as the height of the fusion-zone is increased. If, after several days running with an abnormally high fusion-zone, the dew-point again rises, the effect is frequently to lower the fusion-zone suddenly, coincident with the falling-off of the grade-heat. This sudden lowering of the fusion-zone causes the stock to come in contact with that portion of the bosh-walls which was superheated during the period of low dew-point, and tends to stick and form scaffolds. These incipient scaffolds afterward give way under the weight of the stock, causing slips and slides, with accompanying troubles.

If a furnace is normally "underburdened," if such an expression may be used, a change in atmospheric moisture does not usually produce as marked an effect on the furnace, since the total heat-energy developed in the furnace is greater than should be required, and the effect of an absorption of heat by increased amount of moisture in the blast would not be as noticeable as if the furnace were carrying a full burden. On the other hand, No. 1 furnace, which was usually underburdened, had a greater tendency to form incipient scaffolds than did No. 2, which usually carried a full burden.

Up to the time these systematic observations were made, much trouble has always been experienced from scaffolds, especially during the months of January and February. During these months in the south the fluctuations in the moisture is apt to be very great, and consequently the conditions conducive to the formation of scaffolds occur most frequently. Moreover, the dew-point is apt to be low for several days, thus tending to increase the height of the fusion-zone, and then rise quite rapidly, causing a sudden contraction in the fusion-zone, with a tendency toward the formation of scaffolds. When the most frequent cause of these irregularities was appreciated, proper steps were taken whenever a marked change in the dew-point indicated the necessity. By careful controlling of the burden, etc., according to the indications, as shown by the hygrometer, many of these irregularities, which had previously been such a serious cause of trouble, could be overcome. Thus, in many instances, when the foundry-man perceived that the dew-point was rapidly rising, he would put in an extra charge of fuel without any ore. This extra fuel would prevent the grade-heat from falling, but, as it was not registered in the furnace-book, it is not shown in the curves.

In the summer months, although the dew-point was very high, the fluctuations were usually confined to rather narrow limits, so that the furnace would not carry as heavy an ore-burden as during the colder months; but the work of the furnace was apt to be more regular than during the winter months.

While it is extremely difficult to express in numbers the exact saving that would be effected in blast-furnace practice by removal of the moisture from the air, my two years of close observation of the influence of atmospheric changes on the furnace-operation convinced me that at least two-thirds if not three-fourths of the irregularities in blast-furnace running were directly attributable to the varying amount of moisture entering the furnace. The lack of uniformity in the grade of the iron, and the irregularity in the running of the furnace, is due not so much to the amount of moisture entering into the furnace at a given time as the fluctuations in the amount of moisture on different days.

I cannot but feel that, if Mr. Gayley has succeeded, as he apparently has, in reducing the amount of moisture to a small and constant amount, his invention will eventually prove to be the most important advance in the metallurgy of pig-iron since the introduction by Neilson of the hot blast, more than 75 years ago.

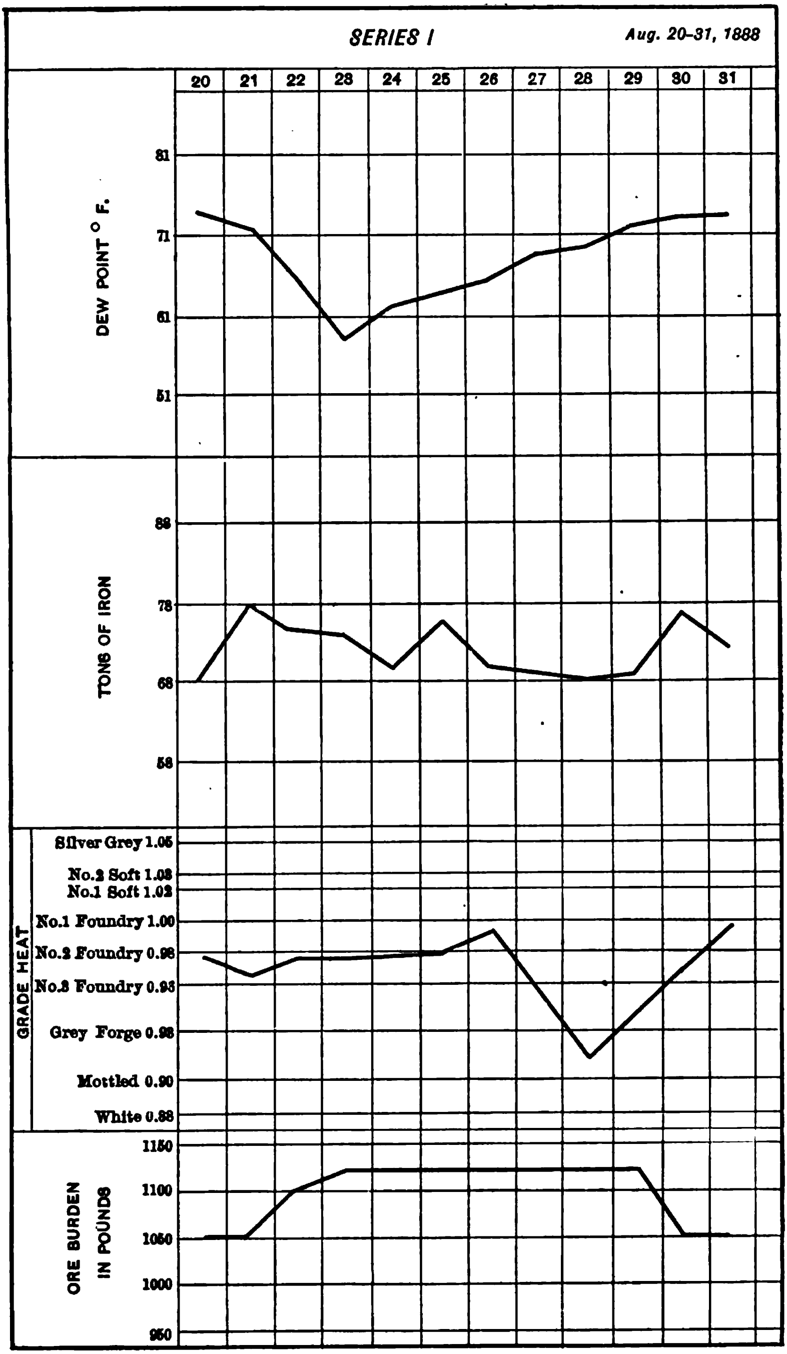
TABLE I.—*Data of Blast-Furnace Operations at Dayton, Tenn.*

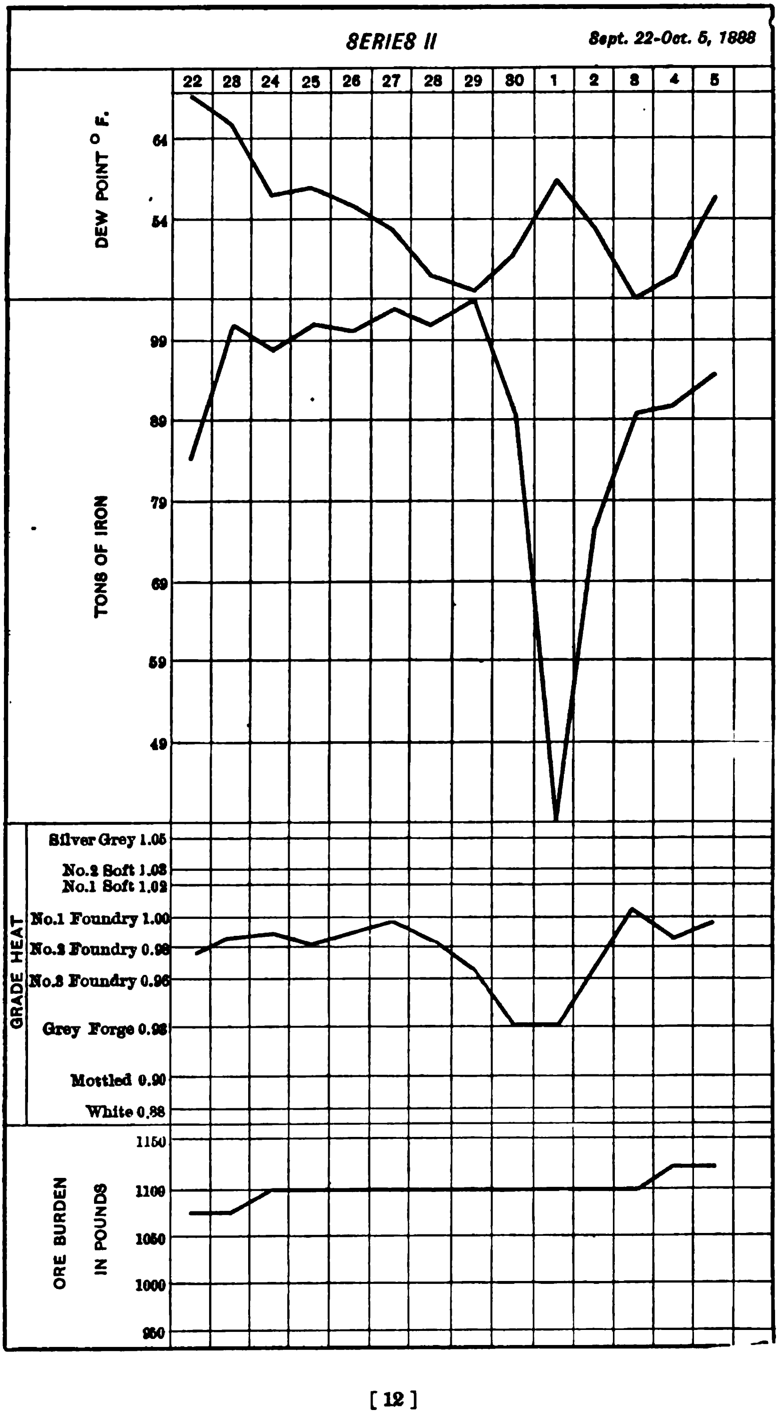
Series.	Date.	Dew-Point.	Coke for Decomposition of Moisture.	Daily Output of Iron.	Grade-Heat.	Ore-Burden.
	1888.	°F.	Pounds.	Tons.		Pounds
I.	Aug. 20.	74	32.48	68	0.977	1,050
	Aug. 21.	72	29.72	78	0.969	1,050
	Aug. 22.	66	24.92	75	0.975	1,100
	Aug. 23.	58	18.11	74	0.975	1,125
	Aug. 24.	62	22.03	70	0.979	1.125
	Aug. 25.	65	24.92	76	0.980	1,125
	Aug. 26.	66	24.50	70	0.993	1,125
	Aug. 27.	69	26.07	69	0.957	1,125
	Aug. 28.	70	23.44	68	0.915	1,125
	Aug. 29.	72	27.67	69	0.945	1,125
	Aug. 30.	73	30.69	77	0.973	1,050
	Aug. 31.	73	30.69	71	0.997	1,050
II.	Sept. 22.	70	26.91	84	0.976	1,075
	Sept. 23.	66	24.50	101	0.985	1,075
	Sept. 24.	57	18.13	98	0.988	1,100
	Sept. 25.	58	18.44	101	0.983	1,100
	Sept. 26.	56	17.54	100	0.989	1,100
	Sept. 27.	53	15.83	103	0.997	1,100
	Sept. 28.	47	13.28	101	0.985	1,100
	Sept. 29.	45	12.79	104	0.968	1,100
	Sept. 30.	50	14.27	90	0.930	1,100

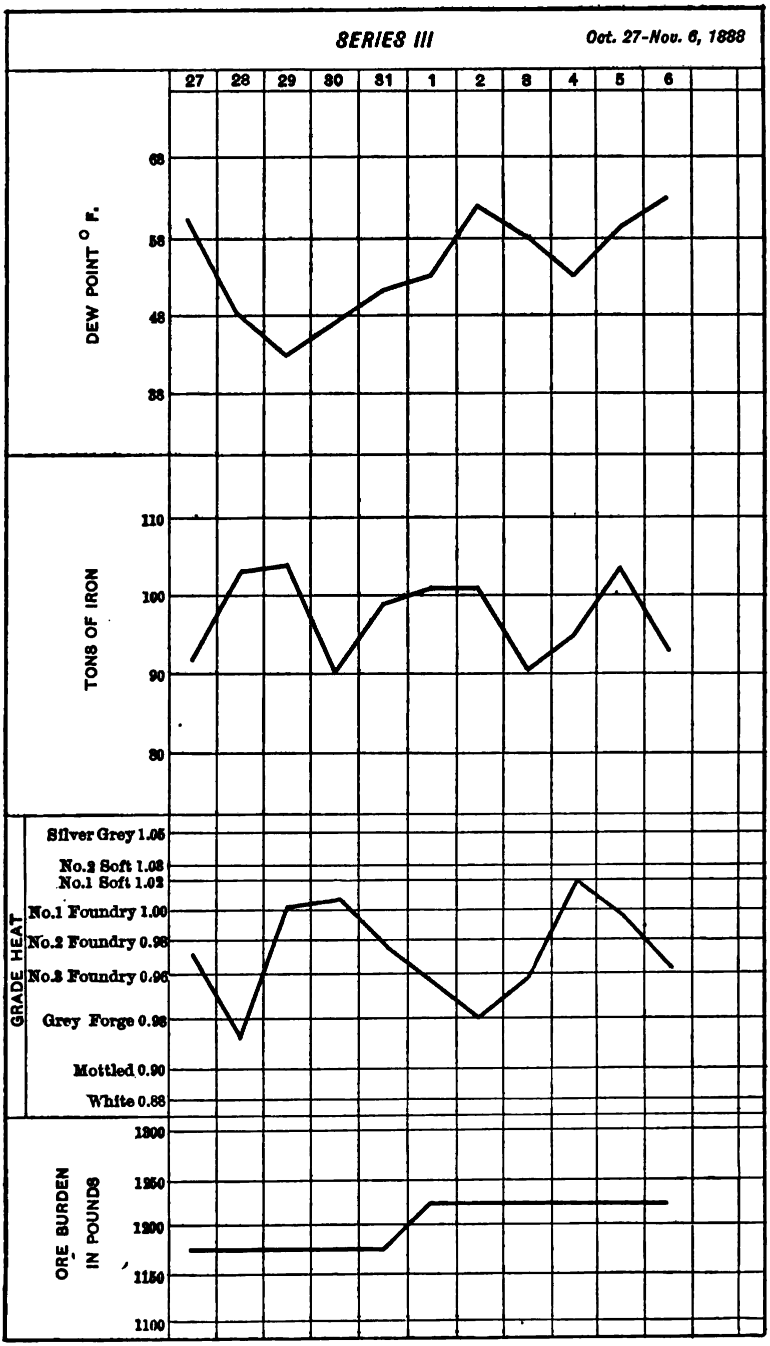
	Oct. 1.	59	17.58	39	0.930	1,100
	Oct. 2.	53	14.87	76	0.964	1,100
	Oct. 3.	44	11.16	90	1.003	1,100
	Oct. 4.	47	12.51	91	0.989	1,125
	Oct. 5.	57	18.60	95	0.996	1,125
III.	Oct. 27.	60	19.56	92	0.970	1,175
	Oct. 28.	48	12.49	103	0.918	1,175
	Oct. 29.	43	10.66	104	1.000	1,175
	Oct. 30.	47	12.62	90	1.005	1,175
	Oct. 31.	51	13.99	99	0.975	1,175
	Nov. 1.	53	14.74	101	0.953	1,225
	Nov. 2.	62	19.99	101	0.930	1,225
	Nov. 3.	58	17.14	90	0.958	1,225
	Nov. 4.	53	15.29	95	1.020	1,225
	Nov. 5.	59	19.41	104	0.997	1,225
	Nov. 6.	63	21.25	93	0.962	1,225
IV.	Dec. 16.	52	14.62	101	0.991	1,200
	Dec. 17.	45	11.04	91	0.945	1,200
	Dec. 18.	33	7.09	101	0.984	1,200
	Dec. 19.	25	5.65	90	1.026	1,200
	Dec. 20.	27	6.56	98	1.029	1,250
	Dec. 21.	28	6.15	105	1.020	1,250
	Dec. 22.	26	5.70	101	0.986	1,250
	Dec. 23.	21	4.38	89	0.984	1,250
	Dec. 24.	40	10.21	93	1.018	1,200
	Dec. 25.	43	11.33	93	1.008	1,200
	Dec. 26.	44	11.06	79	1.008	1,200
	Dec. 27.	37	8.40	69	0.945	1,200
	1889.					
V.	Feb. 12.	26	6.00	78	1.012	1,050
	Feb. 13.	33	7.96	89	1.082	1,050
	Feb. 14.	44	11.75	89	0.917	1,050
	Feb. 15.	51	14.50	80	0.900	1,050
	Feb. 16.	57	16.88	80	0.904	1,050
	Feb. 17.	58	18.11	80	0.930	1,075
	Feb. 18.	33	7.62	88	0.962	1,125
	Feb. 19.	24	5.49	95	0.994	1,150
	Feb. 20.	29	6.73	96	0.993	1,150
	Feb. 21.	29	6.61	86	0.940	1,150
	Feb. 22.	32	7.41	87	0.986	1,150
	Feb. 23.	25	5.60	74	1.013	1,150
VI.	Apr. 1.	52	14.22	84	0.936	1,150
	Apr. 2.	48	12.61	98	0.985	1,150
	Apr. 3.	46	11.85	100	1.041	1,150
	Apr. 4.	38	8.94	102	1.001	1,150
	Apr. 5.	41	10.16	91	1.010	1,150
	Apr. 6.	28	6.48	101	1.007	1,150
	Apr. 7.	39	8.97	105	0.992	1,150
	Apr. 8.	41	9.98	102	0.942	1,150
VII.	Sept. 16.	70	27.39	95.5	0.964	1,060
	Sept. 17.	63	21.82	94.5	0.970	1,060
	Sept. 18.	48	13.64	101	1.020	1,060
	Sept. 19.	47	12.40	102	0.992	1,080
	Sept. 20.	52	15.42	103	1.005	1,100
	Sept. 21.	53	15.70	102	0.978	1,060
	Sept. 22.	53	15.01	101	0.932	1,060
	Sept. 23.	59	19.42	101	0.951	1,060
	Sept. 24.	64	23.53	98	0.999	1,060
	Sept. 25.	61	20.42	101	0.967	1,060

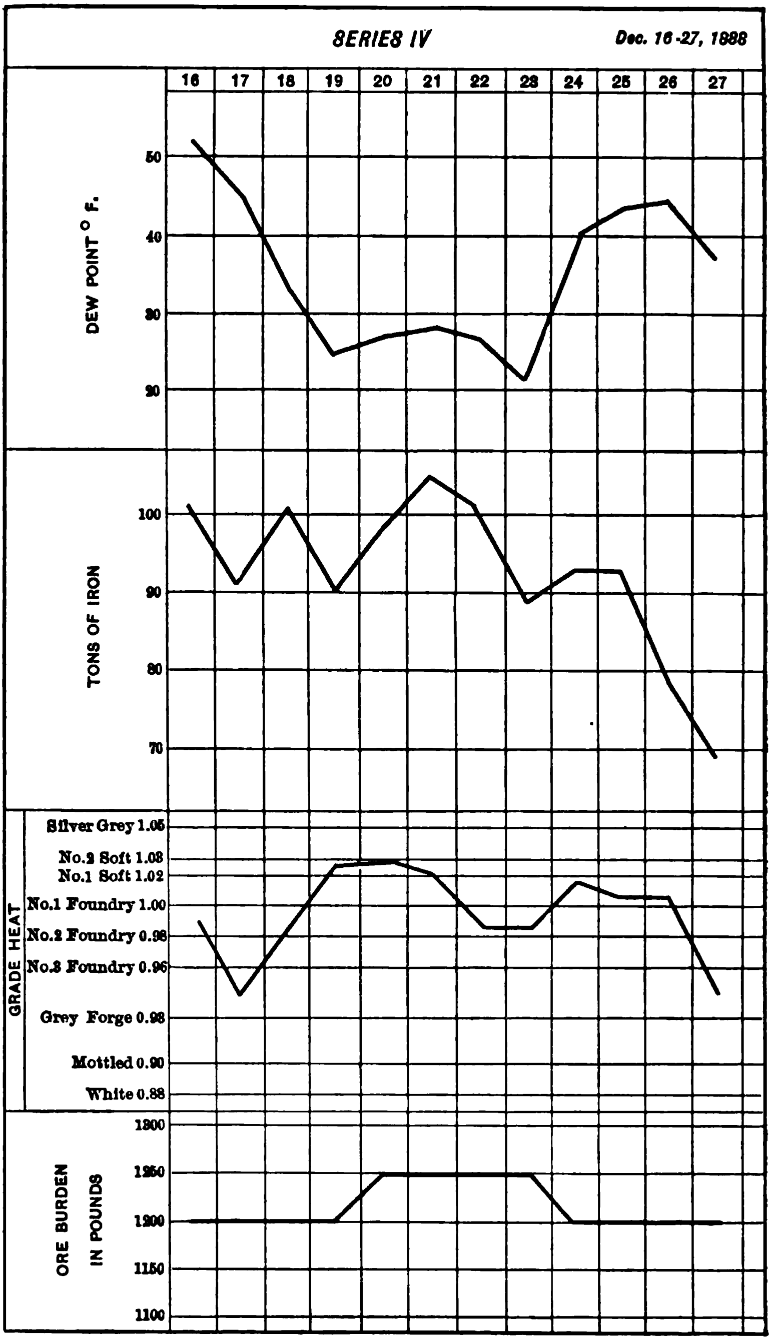
VIII.	Oct. 8.	37	8.64	102	0.960	1,100
	Oct. 9.	44	11.16	102	0.937	1,100
	Oct. 10.	51	14.25	102	0.945	1,060
	Oct. 11.	53	14.74	102	0.920	1,060
	Oct. 12.	59	20.42	102	0.998	1,060
	Oct. 13.	59	20.75	97	0.968	1,060
	Oct. 14.	39	Cleaning flues.			
	Oct. 15.	41	10.07	85	0.972	1,060
	Oct. 16.	41	10.42	92	0.933	1,060
	Oct. 17.	50	14.27	102	0.974	1,060
	Oct. 18.	46	11.96	92	0.960	1,060
	Oct. 19.	51	13.74	96	0.955	1,060
IX.	Nov. 26.	52	15.41	94	0.995	1,060
	Nov. 27.	45	11.55	94	0.996	1,040
	Nov. 28.	31	7.26	96	1 007	1,040
	Nov. 29.	25	5.51	94	0.968	1,040
	Nov. 30.	28	6.37	98	0.968	1,040
	Dec. 1.	34	7.73	96	0.939	1,040
	Dec. 2.	28	6.37	98	0.957	1,040
	Dec. 3.	40	9.61	96	0.946	1,040
	Dec. 4.	42	10.16	96	0.978	1,040
	Dec. 5.	48	12.61	95	0.942	1,040
	Dec. 6.	50	14.51	95	0.975	1,040
	Dec. 7.	57	17.19	94	0.976	1,040
	Dec. 8.	57	17.04	96	0.957	1,040
	Dec. 9.	61	19.70	94	0.956	1,020
	Dec. 10.	60	19.56	96	0.971	1,020
X.	Dec. 15.	46	12.18	95	1.000	1,060
	Dec. 16.	47	12.84	96	0.994	1,060
	Dec. 17.	56	17.54	97	0.996	1,060
	Dec. 18.	57	18.13	95	1.020	1,060
	Dec. 19.	57	18.13	93	0.979	1,060
	Dec. 20.	59	17.74	64	1.020	1,060
	Dec. 21.	60	19.91	94	0.987	1,060
	Dec. 22.	55	16.36	96	1.020	1,060
	1890.					
XI.	Jan. 9.	41	9.89	91	0.967	1,050
	Jan. 10.	55	16.22	96	0.949	1,050
	Jan. 11.	59	17.07	94	0.923	1,050
	Jan. 12.	56	16.33	91	0.930	1,025
	Jan. 13.	39	8.81	83	0.952	1,025
	Jan. 14.	40	9.78	104	0.962	1,025
	Jan. 15.	50	13.53	97	0.985	1,050
	Jan. 16.	26	5.64	95	0.952	1,050
	Jan. 17.	30	6.80	102	0.971	1,050
	Jan. 18.	34	7.88	95	0.988	1,050
	Jan. 19.	53	15.56	92	0.973	1,050
XII.	Jan. 20.	56	16.48	93	0.956	1,050
	Jan. 21.	37	18.87	96	0.983	1,050
	Jan. 22.	27	5.88	93	0.945	1,060
	Jan. 23.	37	8.79	105	0.990	1,060
	Jan. 24.	32	6.71	90	0.932	1,060
	Jan. 25.	40	8.58	95	0.940	1,060
	Jan. 26.	54	14.84	93	0.948	1,060
	Jan. 27.	50	12.92	95	0.955	1,060
	Jan. 28.	38	8.62	92	0.995	1,060
	Jan. 29.	43	9.79	78	0.974	1,075
	Jan. 30.	45	10.73	104	0.965	1,075
	Jan. 31.	50	12.67	102	0.957	1,075

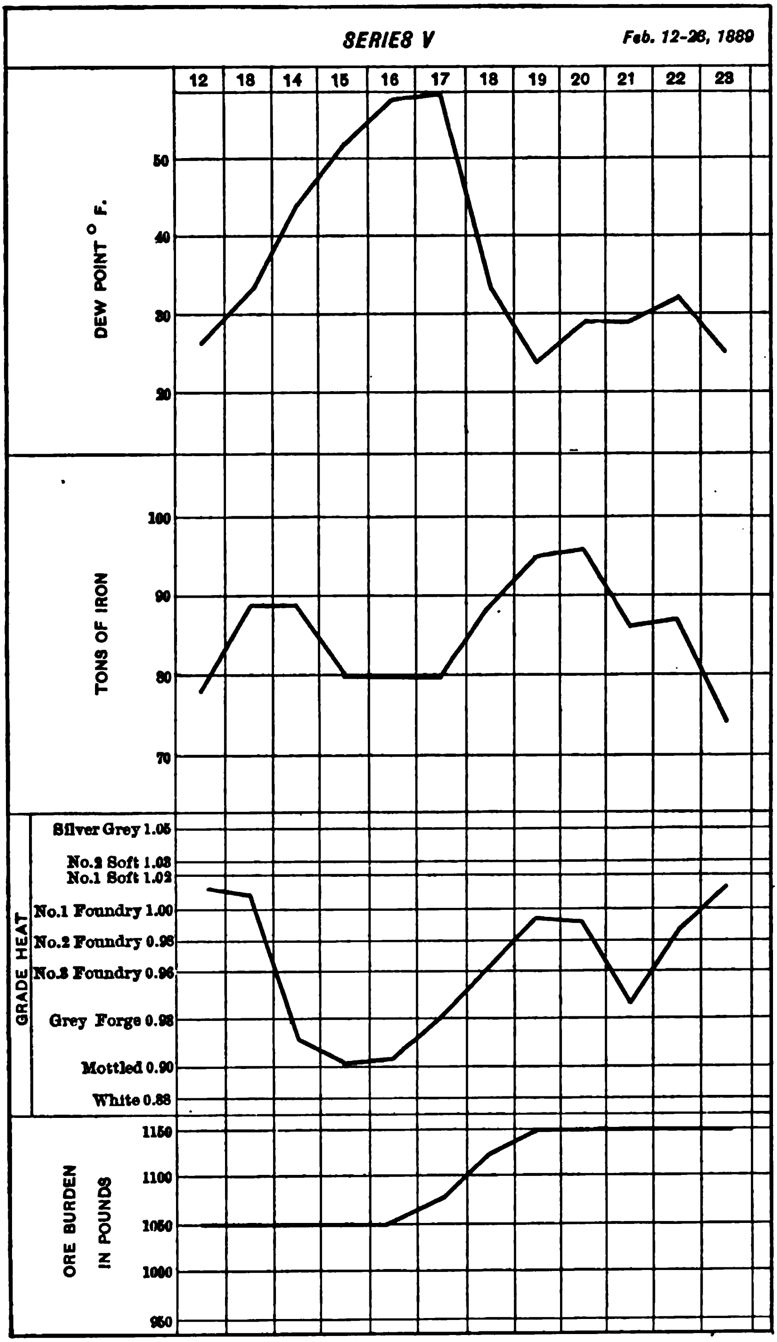
XIII.	Feb. 15.	43	11.04	96	0.981	1,100
	Feb. 16.	45	12.30	108	0.977	1,100
	Feb. 17.	48	13.14	92	0.970	1,100
	Feb. 18.	55	16.80	102	0.970	1,100
	Feb. 19.	60	18.69	102	0.939	1,050
	Feb. 20.	38	8.62	108	0.914	1,060
	Feb. 21.	33	7.36	100	0.960	1,070
	Feb. 22.	33	7.89	98	1.000	1,070
	Feb. 23.	45	11.87	96	0.954	1,070
	Feb. 24.	61	20.78	100	0.993	1,070
	Feb. 25.	65	22 68	93	0.951	1,035
	Feb. 26.	63	21.82	84	0.947	1,035
XIV.	Feb. 27.	63	20.48	100	0.936	1,035
	Feb. 28.	44	11.55	117	0.937	1,200
	Mar. 1.	18	4.10	130	0.978	1,200
	Mar. 2.	19	4.05	111	0.978	1,200
	Mar. 3.	31	6.40	80	0.915	1,200
	Mar. 4.	36	8.26	95	0.928	1,200
	Mar. 5.	39	8.94	92	0.943	1,200
	Mar. 6.	27	5.88	91	0.973	1,200
	Mar. 7.	28	6.15	91	0.945	1,200
	Mar. 8.	31	6.89	98	0.949	1,150
	Mar. 9.	34	7.73	100	0.974	1,150
	Mar. 10.	45	11.35	91	1.007	1,150
	Mar. 11.	53	15.56	94	0.987	1,150
	Mar. 12.	58	17.46	92	0.966	1,150
XV.	Apr. 23.	58	17.14	93	0.917	1,075
	Apr. 24.	64	21.15	92	0.967	1,050
	Apr. 25.	65	21.86	88	0.911	1,050
	Apr. 26.	61	18.98	99	0.911	1,050
	Apr. 27.	52	14.75	81	0.937	1,050
	Apr. 28.	48	13.18	95	0.941	1,050
	Apr. 29.	51	14.37	99	0.977	1,050
	Apr. 30.	57	17.19	104	0.963	1,025
	May 1.	58	16.82	93	0.936	1,025
	May 2.	59	17.74	91	0.956	1,025
	May 3.	60	18.52	90	0.979	1,000
	May 4.	63	21.82	96	1.002	1,000
	May 5.	62	22.21	91	1.013	1,000
XVI.	June 1.	64	21.75	90	0.960	1,000
	June 2.	68	25.46	85	0.950	1,000
	June 3.	66	24.08	91	0.980	1,000
	June 4.	69	27.47	83	0.963	1,000
	June 5.	69	27.87	87	0.960	1,000
	June 6.	68	26.36	87	0.981	1,000
	June 7.	61	20.60	90	0.960	1,050
	June 8.	65	23.29	91	0.989	1,050
	June 9.	69	26.54	91	0.970	1,050
	June 10.	70	26.43	88	0.962	1,050
	June 11.	70	28.12	91	1.002	1,050
	June 12.	66	23.44	87	0.952	1,050
	June 13.	70	28.12	90	0.967	1,050
	June 14.	70	27.39	89	0.982	1,025

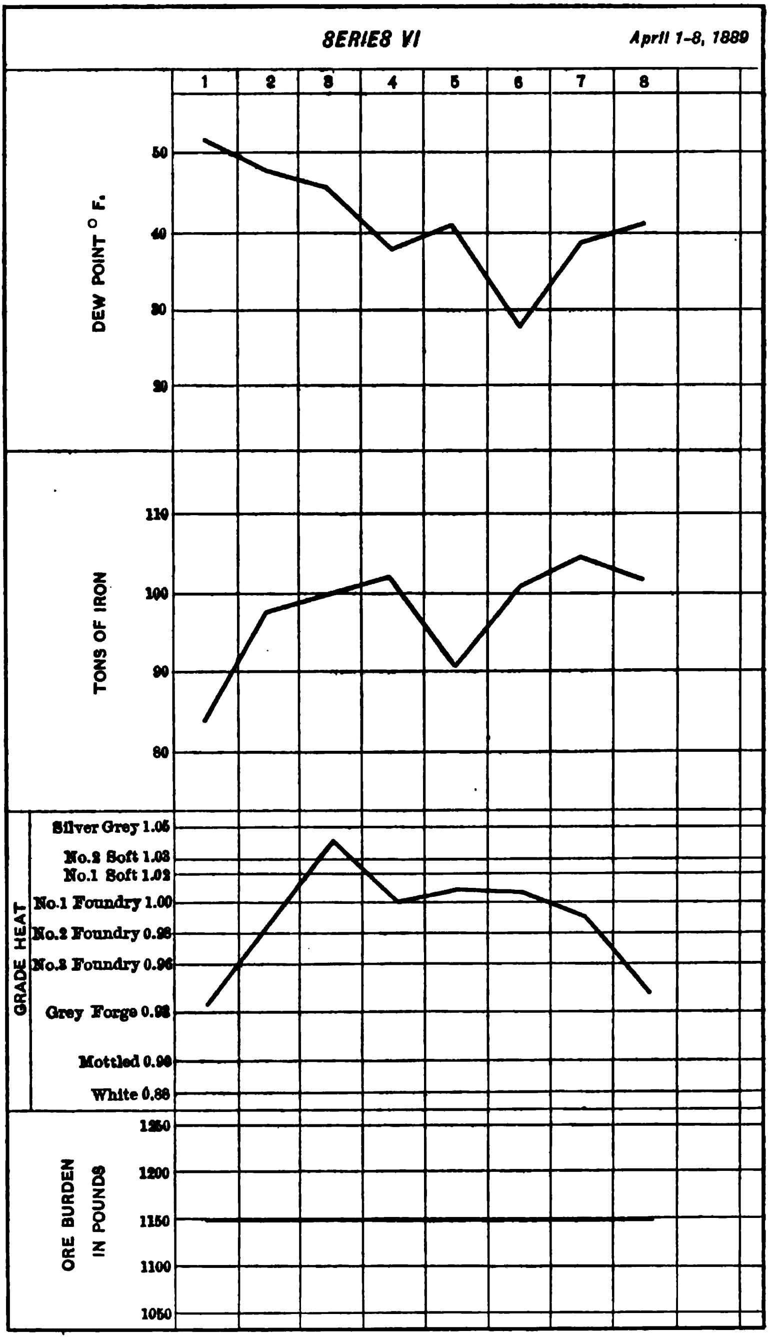

SERIES I
Aug. 20-31, 1888
20
21
22
23
24
25
26
27
28
29
30
31
DEW POINT ° F.
81
71
61
51
TONS OF IRON
88
78
68
58
GRADE HEAT
Silver Grey 1.05
No.2 Soft 1.03
No.1 Soft 1.02
No.1 Foundry 1.00
No.2 Foundry 0.98
No.3 Foundry 0.95
Grey Forge 0.93
Mottled 0.90
White 0.88
ORE BURDEN IN POUNDS
1150
1100
1050
1000
950

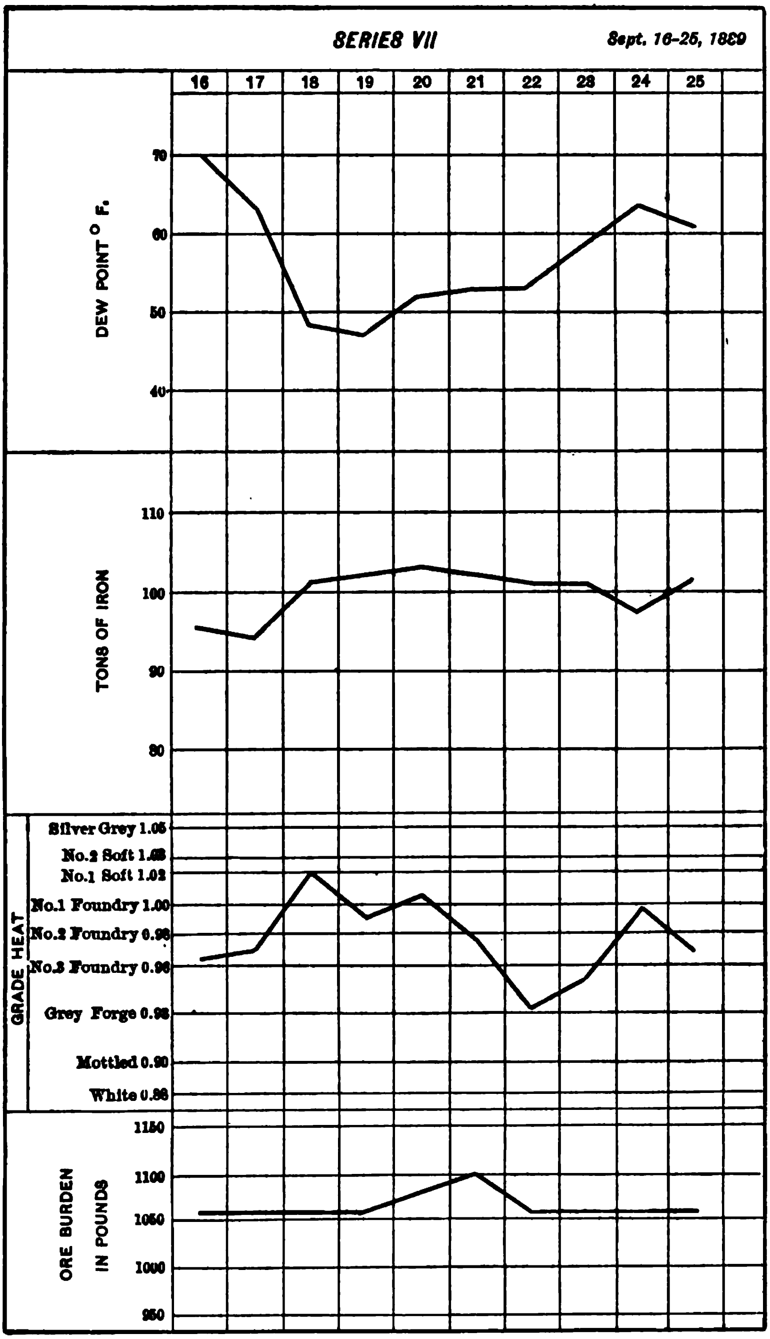

SERIES II
Sept. 22-Oct. 5, 1888
22
23
24
25
26
27
28
29
30
1
2
3
4
5
DEW POINT ° F.
64
54
TONS OF IRON
99
89
79
69
59
49
GRADE HEAT
Silver Grey 1.05
No.2 Soft 1.03
No.1 Soft 1.02
No.1 Foundry 1.00
No.2 Foundry 0.98
No.3 Foundry 0.96
Grey Forge 0.93
Mottled 0.90
White 0.88
ORE BURDEN
IN POUNDS
1150
1100
1050
1000
950

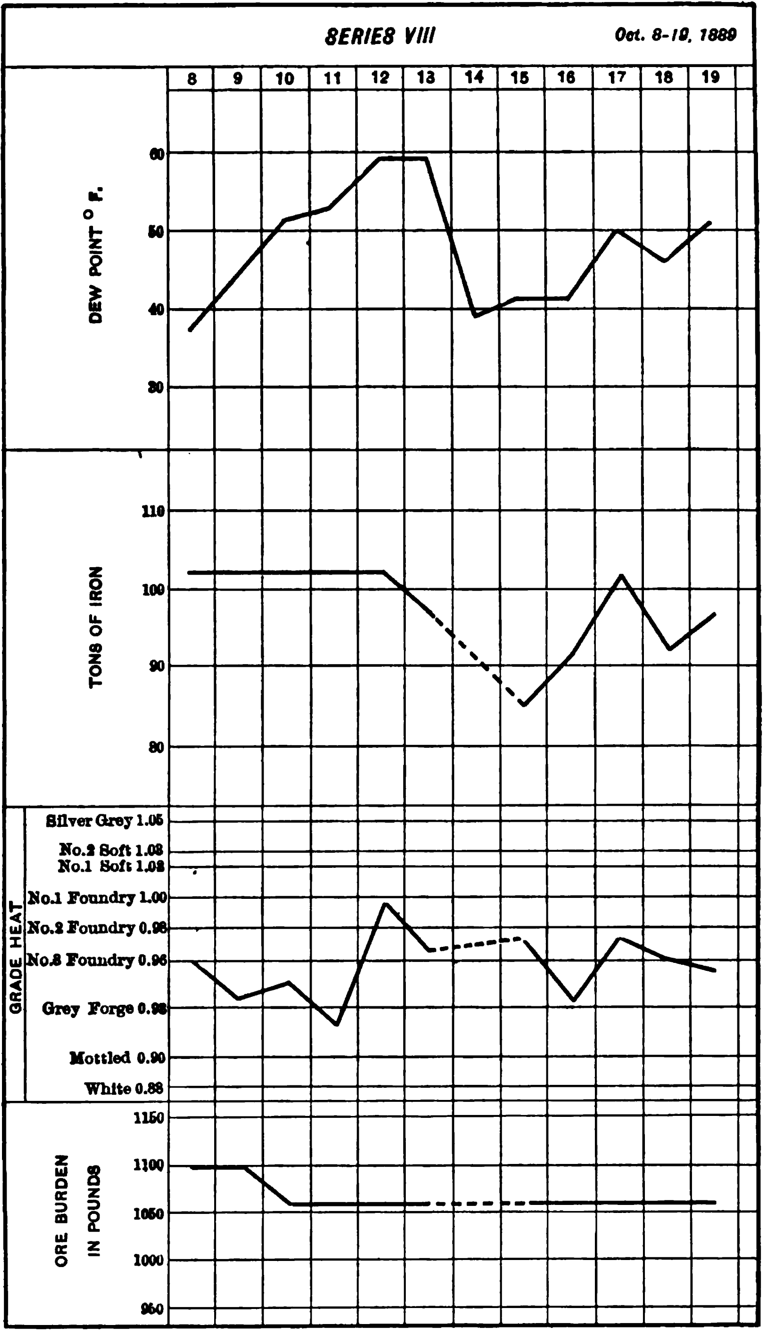

SERIES III
Oct. 27-Nov. 6, 1888
27
28
29
30
31
1
2
3
4
5
6
DEW POINT ° F.
68
58
48
38
TONS OF IRON
110
100
90
80
GRADE HEAT
Silver Grey 1.05
No.2 Soft 1.03
No.1 Soft 1.02
No.1 Foundry 1.00
No.2 Foundry 0.98
No.3 Foundry 0.96
Grey Forge 0.93
Mottled 0.90
White 0.88
ORE BURDEN IN POUNDS
1300
1250
1200
1150
1100

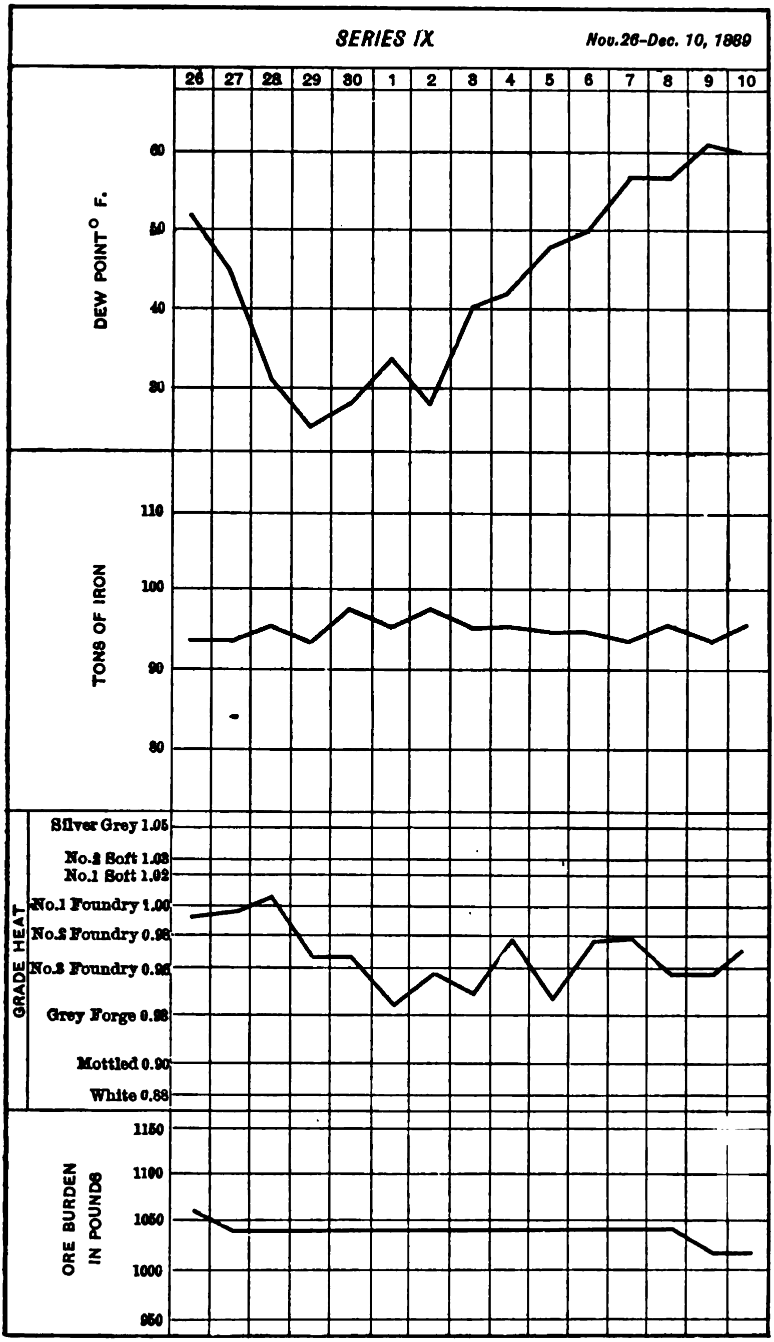

SERIES IV
Dec. 16-27, 1888
16
17
18
19
20
21
22
23
24
25
26
27
DEW POINT ° F.
50
40
30
20
TONS OF IRON
100
90
80
70
GRADE HEAT
Silver Grey 1.05
No.2 Soft 1.03
No.1 Soft 1.02
No.1 Foundry 1.00
No.2 Foundry 0.98
No.3 Foundry 0.96
Grey Forge 0.93
Mottled 0.90
White 0.88
ORE BURDEN IN POUNDS
1300
1250
1200
1150
1100

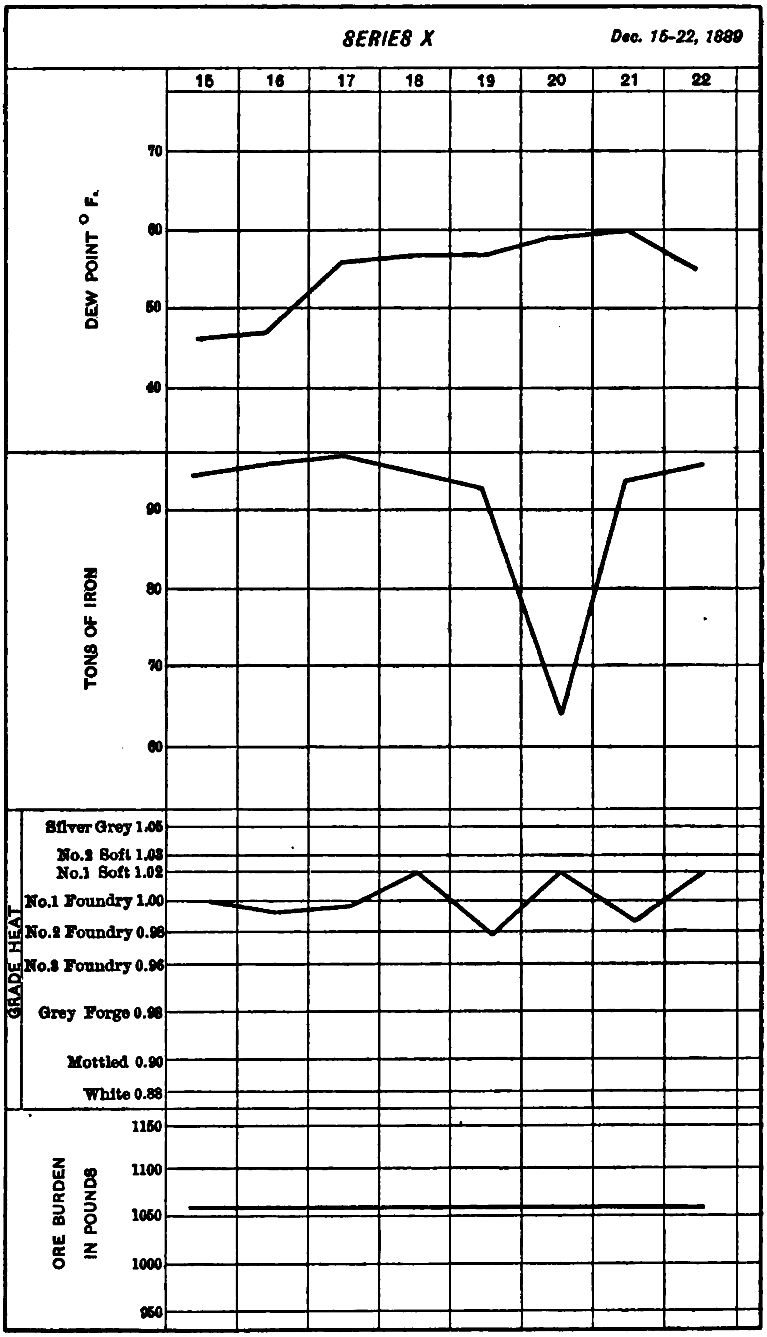

SERIES V
Feb. 12-23, 1889
12
13
14
15
16
17
18
19
20
21
22
23
DEW POINT ° F.
50
40
30
20
TONS OF IRON
100
90
80
70
GRADE HEAT
Silver Grey 1.05
No.2 Soft 1.03
No.1 Soft 1.02
No.1 Foundry 1.00
No.2 Foundry 0.98
No.3 Foundry 0.96
Grey Forge 0.93
Mottled 0.90
White 0.88
ORE BURDEN IN POUNDS
1150
1100
1050
1000
950

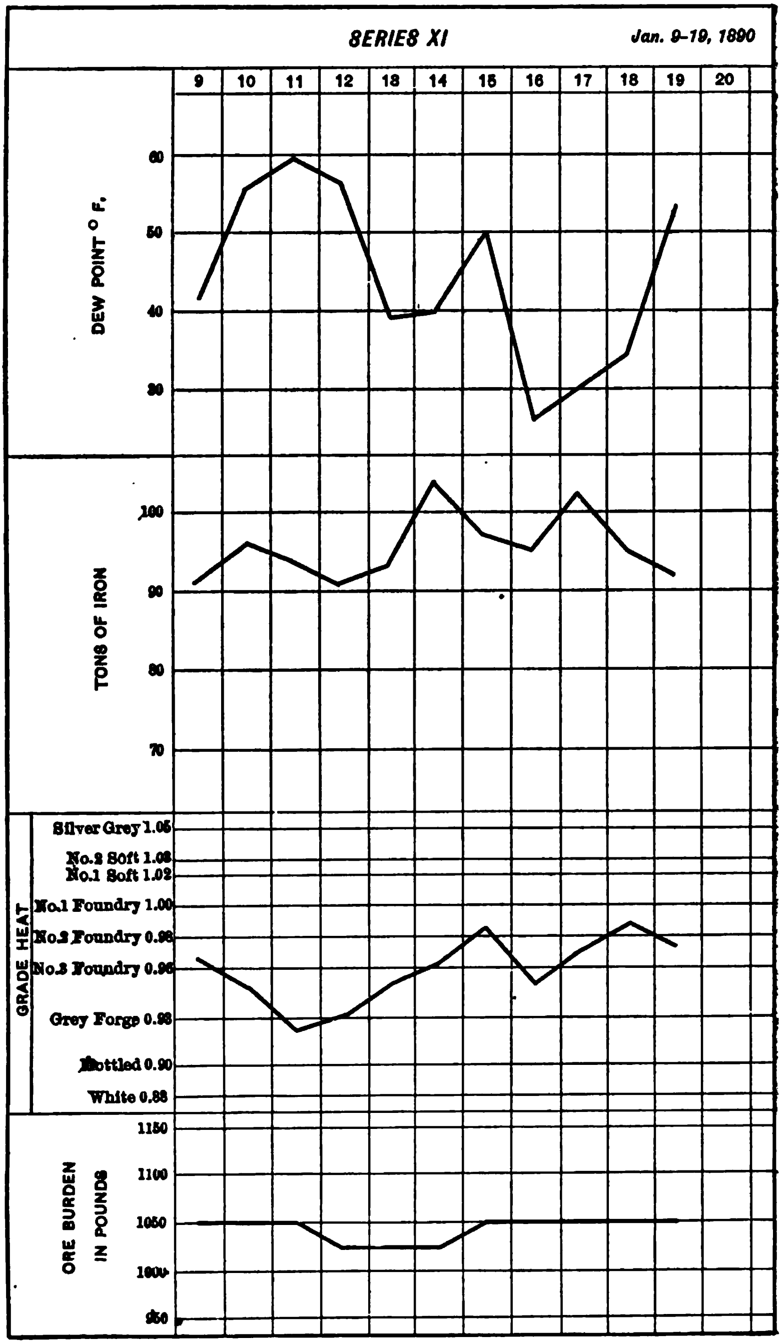

SERIES VI
April 1-8, 1889
1
2
3
4
5
6
7
8
DEW POINT ° F.
50
40
30
20
TONS OF IRON
110
100
90
80
GRADE HEAT
Silver Grey 1.05
No.2 Soft 1.03
No.1 Soft 1.02
No.1 Foundry 1.00
No.2 Foundry 0.98
No.3 Foundry 0.96
Grey Forge 0.93
Mottled 0.90
White 0.88
ORE BURDEN IN POUNDS
1250
1200
1150
1100
1050

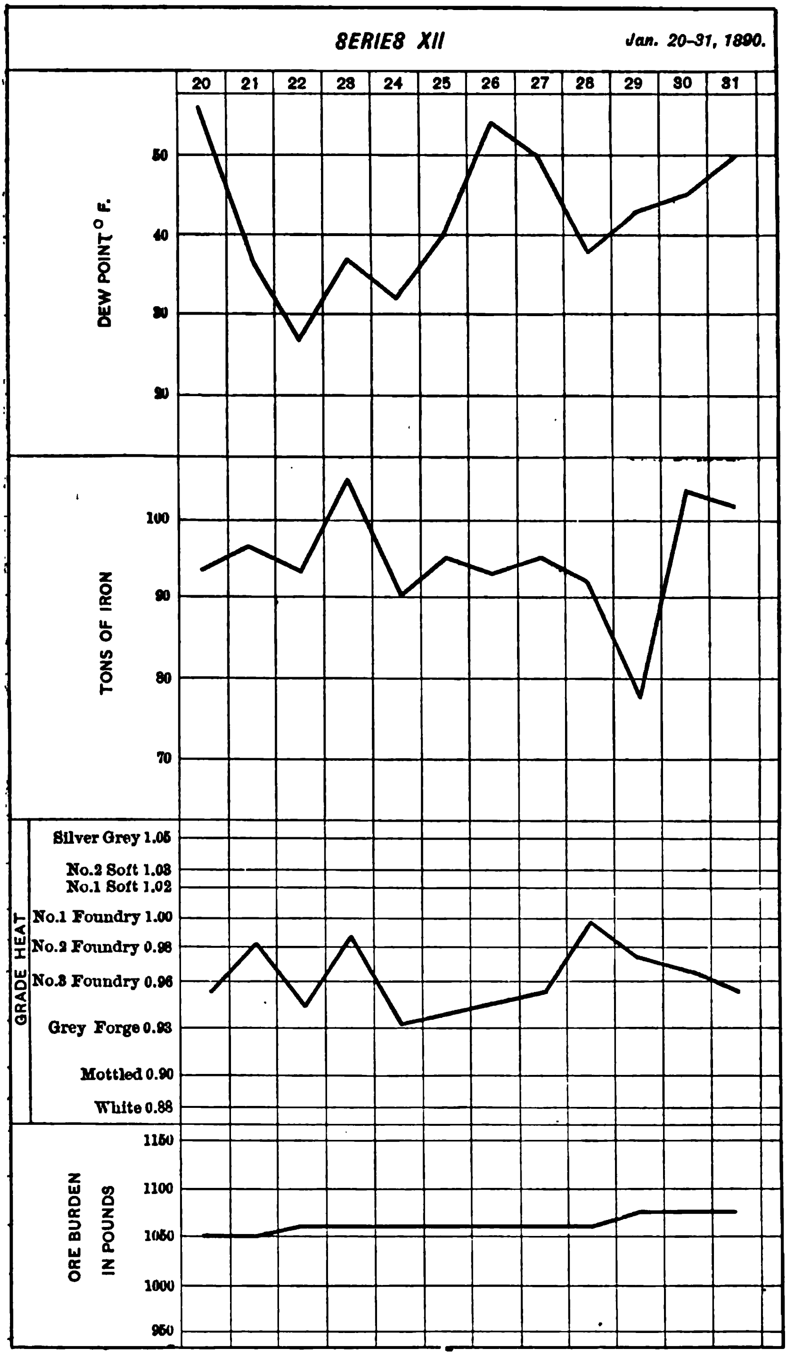

SERIES VII
Sept. 16-25, 1899
16
17
18
19
20
21
22
23
24
25
DEW POINT ° F.
70
60
50
40
TONS OF IRON
110
100
90
80
GRADE HEAT
Silver Grey 1.05
No.2 Soft 1.03
No.1 Soft 1.02
No.1 Foundry 1.00
No.2 Foundry 0.98
No.3 Foundry 0.96
Grey Forge 0.93
Mottled 0.90
White 0.88
ORE BURDEN
IN POUNDS
1150
1100
1050
1000
950

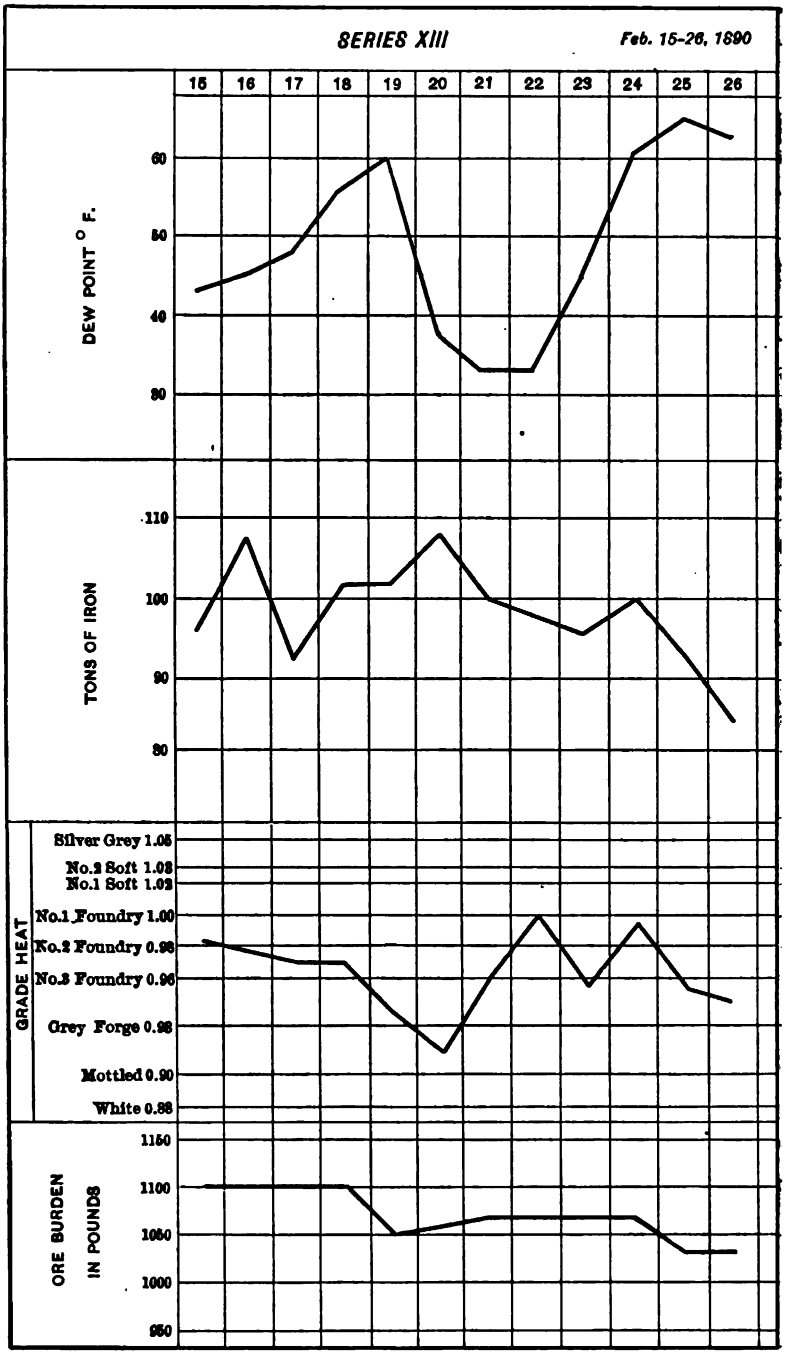

SERIES VIII
Oct. 8-19, 1889
8
9
10
11
12
13
14
15
16
17
18
19
DEW POINT ° F.
60
50
40
30
TONS OF IRON
110
100
90
80
GRADE HEAT
Silver Grey 1.05
No.2 Soft 1.03
No.1 Soft 1.02
No.1 Foundry 1.00
No.2 Foundry 0.98
No.3 Foundry 0.96
Grey Forge 0.93
Mottled 0.90
White 0.88
ORE BURDEN IN POUNDS
1150
1100
1050
1000
950

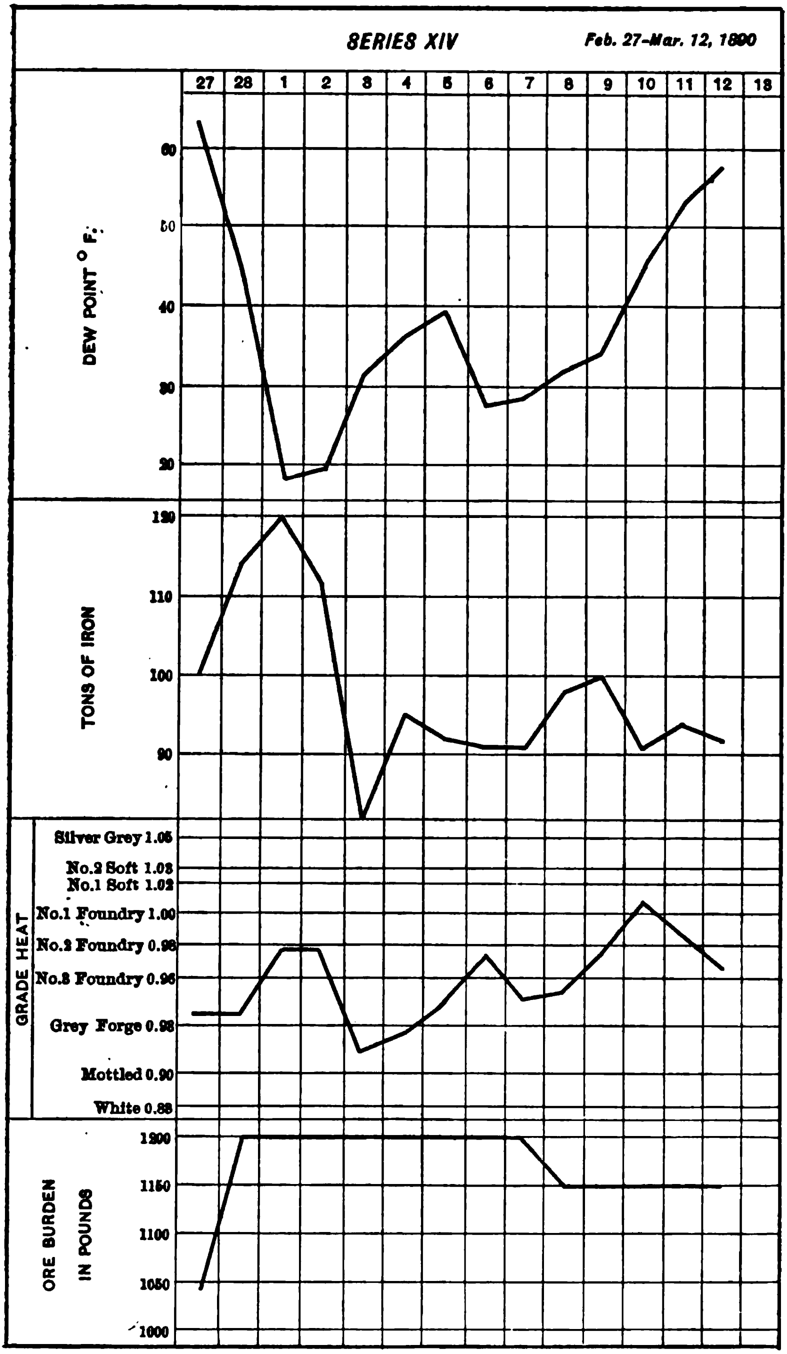

SERIES IX
Nov.26-Dec. 10, 1889
26
27
28
29
30
1
2
3
4
5
6
7
8
9
10
DEW POINT° F.
60
50
40
30
TONS OF IRON
110
100
90
80
GRADE HEAT
Silver Grey 1.05
No.2 Soft 1.03
No.1 Soft 1.02
No.1 Foundry 1.00
No.2 Foundry 0.98
No.3 Foundry 0.96
Grey Forge 0.93
Mottled 0.90
White 0.88
ORE BURDEN IN POUNDS
1150
1100
1050
1000
950

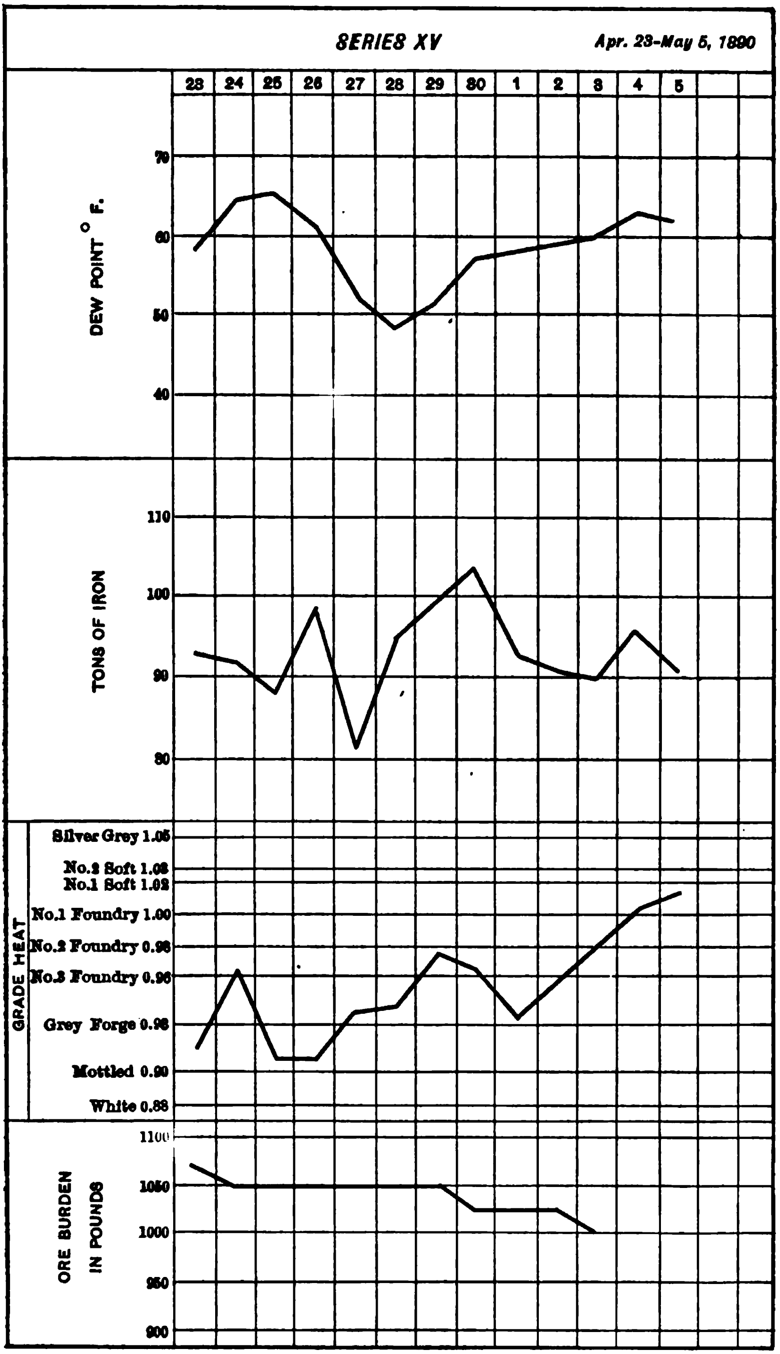

SERIES X
Dec. 15-22, 1889
15
16
17
18
19
20
21
22
DEW POINT ° F.
70
60
50
40
TONS OF IRON
90
80
70
60
GRADE HEAT
Silver Grey 1.05
No.2 Soft 1.03
No.1 Soft 1.02
No.1 Foundry 1.00
No.2 Foundry 0.98
No.3 Foundry 0.96
Grey Forge 0.93
Mottled 0.90
White 0.88
ORE BURDEN IN POUNDS
1150
1100
1050
1000
950

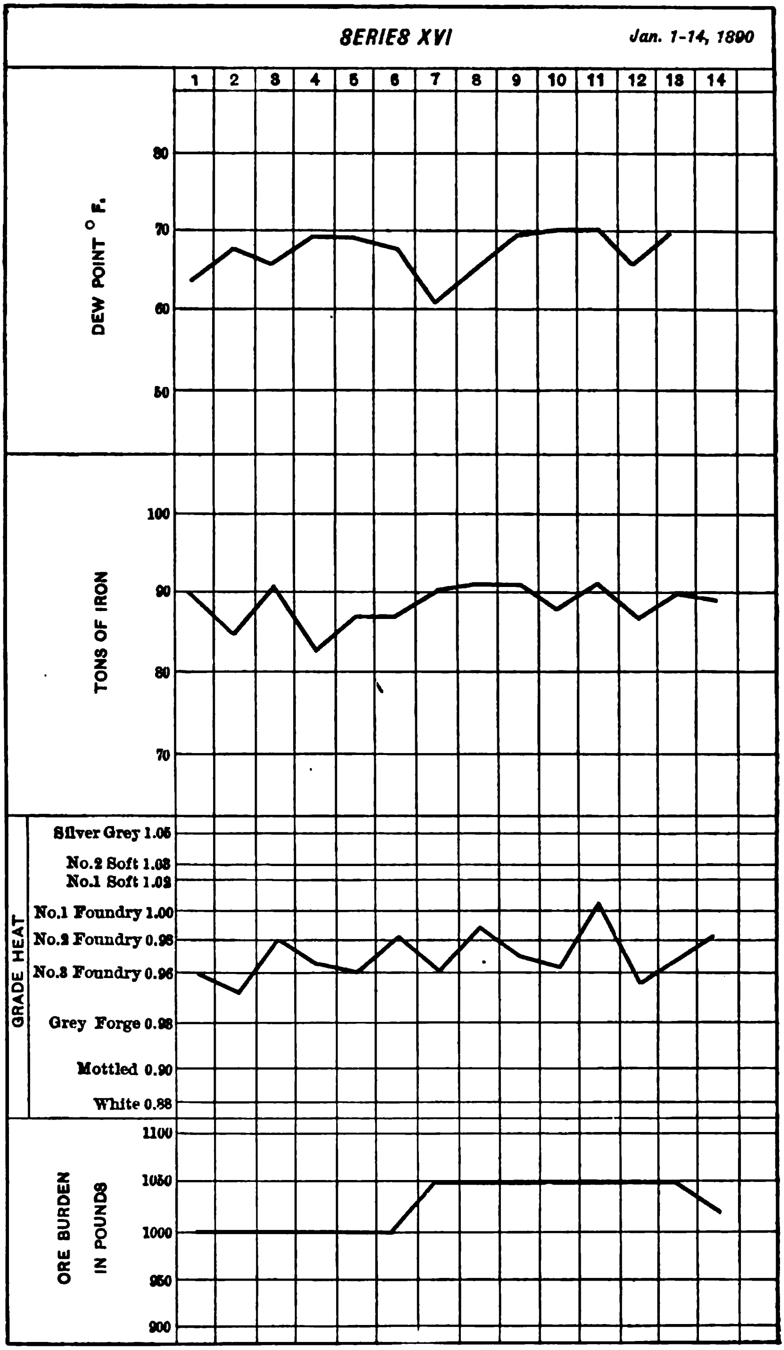

SERIES XI
Jan. 9-19, 1890
9
10
11
12
13
14
15
16
17
18
19
20
DEW POINT ° F.
60
50
40
30
TONS OF IRON
100
90
80
70
GRADE HEAT
Silver Grey 1.05
No.2 Soft 1.03
No.1 Soft 1.02
No.1 Foundry 1.00
No.2 Foundry 0.98
No.3 Foundry 0.96
Grey Forge 0.93
Mottled 0.90
White 0.88
ORE BURDEN IN POUNDS
1150
1100
1050
1000
950


SERIES XII
Jan. 20-31, 1890.
20
21
22
23
24
25
26
27
28
29
30
31
DEW POINT ° F.
50
40
30
20
TONS OF IRON
100
90
80
70
GRADE HEAT
Silver Grey 1.05
No.2 Soft 1.03
No.1 Soft 1.02
No.1 Foundry 1.00
No.2 Foundry 0.98
No.3 Foundry 0.96
Grey Forge 0.93
Mottled 0.90
White 0.88
ORE BURDEN IN POUNDS
1150
1100
1050
1000
950


SERIES XIII
Feb. 15-26, 1890
15
16
17
18
19
20
21
22
23
24
25
26
DEW POINT ° F.
60
50
40
30
TONS OF IRON
110
100
90
80
GRADE HEAT
Silver Grey 1.05
No.2 Soft 1.03
No.1 Soft 1.02
No.1 Foundry 1.00
No.2 Foundry 0.98
No.3 Foundry 0.96
Grey Forge 0.93
Mottled 0.90
White 0.88
ORE BURDEN
IN POUNDS
1150
1100
1050
1000
950


SERIES XIV
Feb. 27-Mar. 12, 1890
27
28
1
2
3
4
5
6
7
8
9
10
11
12
13
DEW POINT ° F.
60
50
40
30
20
TONS OF IRON
120
110
100
90
GRADE HEAT
Silver Grey 1.05
No.2 Soft 1.03
No.1 Soft 1.02
No.1 Foundry 1.00
No.2 Foundry 0.98
No.3 Foundry 0.96
Grey Forge 0.93
Mottled 0.90
White 0.88
ORE BURDEN IN POUNDS
1200
1150
1100
1050
1000


SERIES XV
Apr. 23-May 5, 1890
23
24
25
26
27
28
29
30
1
2
3
4
5
DEW POINT ° F.
70
60
50
40
TONS OF IRON
110
100
90
80
GRADE HEAT
Silver Grey 1.05
No.2 Soft 1.03
No.1 Soft 1.02
No.1 Foundry 1.00
No.2 Foundry 0.98
No.3 Foundry 0.96
Grey Forge 0.93
Mottled 0.90
White 0.88
ORE BURDEN
IN POUNDS
1100
1050
1000
950
900


SERIES XVI
Jan. 1-14, 1890
1
2
3
4
5
6
7
8
9
10
11
12
13
14
DEW POINT ° F.
80
70
60
50
TONS OF IRON
100
90
80
70
GRADE HEAT
Silver Grey 1.05
No.2 Soft 1.03
No.1 Soft 1.02
No.1 Foundry 1.00
No.2 Foundry 0.98
No.3 Foundry 0.96
Grey Forge 0.93
Mottled 0.90
White 0.88
ORE BURDEN IN POUNDS
1100
1050
1000
950
900

[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

The Effect of Silver on the Chlorination and Bromination of Gold.

A Reply to the Discussion, by T. K. Rose, of the paper by H. O. Hofman and M. G. Magnuson, read at the British Columbia Meeting, July, 1905.

(Bethlehem Meeting, February, 1906.)

H. O. HOFMAN, Boston, Mass. (communication to the Secretary*):—In chlorinating and brominating silver-bearing gold-ores in revolving barrels, it is found that comparatively little silver is extracted, and it is believed that the silver has a harmful influence upon the yield of the gold. It is this belief which prompted us to undertake the work. As our paper shows, we confined our attention to barrel-work and tried to imitate the large-scale conditions, as far as possible, in a series of laboratory experiments with the two variables;—concentration of solutions and percentages of silver. We did not attempt to solve the purely chemical question of the relative solubility of gold in chlorine and bromine, but had to consider incidentally one phase of it in making the start of our alloy-series with pure gold. A determination of the relative powers of chlorine and bromine to dissolve gold would have required a very different series of tests, in which varying amounts of liquid chlorine and bromine, dissolved in a given amount of water, would have been revolved together in glass-stoppered bottles in the regulation water-bath for different periods of time, and made to act upon the same excess of finely-divided gold. In comparing barrel-chlorination and barrel-bromination as carried out in treating ores, the chlorine solution will probably be warmer at the start than the bromine solution, as pointed out by Dr. Rose, and be therefore liable to act more energetically than its equivalent of bromine; but that lies in the nature of the two processes. Although our paper clearly points to the fact that we confined our work to following the working conditions of ore-treatment in revolving-barrels, a misunderstanding of our purpose would have been excluded if we had stated it in so many words in the text or in the title.

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* Received October 19, 1905.

[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

The Beard-Mackie Sight-Indicator for the Measurement of Marsh-Gas in Collieries.

BY M. H. HARRINGTON, PHILADELPHIA, PA.

(Bethlehem Meeting, February, 1906.)

THE *Transactions* of the Institute afford abundant evidence of the general recognition by mining engineers of the importance of a safety-lamp which will not only give warning of the presence of fire-damp, but will also indicate the proportion in which it is present.[1]

Mining-men are only too familiar with the frequent and sudden changes that constantly occur at the working-face of a gaseous mine. Nothing illustrates more forcibly the pregnant condition of the strata enfolding the seam and the seam itself, than the fact that a circulation of perhaps 150,000 cu. ft. of air may contain 2 or even 3 per cent. of marsh-gas, representing a volume of from 3,000 to 4,000 cu. ft. of this gas pouring out each minute from the natural strata into the mine-workings. It would, indeed, be strange if this great outflow of gas were always constant, and it creates no surprise that such earth-breathings, as they may be called, are spasmodic and irregular in their wane and flow. There are other causes that act to vary the gaseous condition of mine-air. Gas has a tendency, often very manifest in mine-workings and airways, to stratify and, at times, to travel long distances in veins or streams. It is common to catch and lose the gas in the lamp when making a test. At times two lamps, held side by side in an air current, will indicate different gaseous conditions of the passing air. When testing for gas, the lamp may suddenly fill with flame, in a mine-chamber, where a moment before a careful test showed the presence of but 1 per cent. of gas.

It is sometimes remarked that there is little need of detecting a smaller percentage of gas than is revealed by the common

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[1] See *Trans.*, xiii., 129; xiv., 410; and especially the elaborate papers of Profs. Chesneau and Clowes, xxii., 120, 606, with the discussion, xxii, 725.

Davy lamp. This quantity, according to the ability of the observer to discern the flame-cap, will vary from 2.5 to 3 per cent. Indeed, few men are able to discover the slightest indication of gas when the quantity present is as low as 2.5 per cent. In a recent discussion of this subject that took place in a meeting of the Institution of Mining Engineers, England,[2] it was stated that the observance of a minute flame-cap by two individuals will differ according to the object each had in view. An instance was cited where a mine-inspector and a mine-overman, both experienced mining-men, entered a place where the inspector wanted to show the presence of gas; the overman failed to detect the flame-cap, which was plainly visible to the inspector. Shortly after, the inspector failed to see any appearance of gas on the flame in the overman's lamp in another heading where the latter claimed he had found gas. As a matter of fact, there is too much guessing in the method of detecting the presence of gas by the height of the flame-cap, which is very indistinct, except when the proportion of gas reaches 3 per cent.

The papers of Profs. Chesneau and Clowes describe many ingenious devices; several of these, while possessing more or less accuracy, require, as a rule, peculiar and sometimes expensive apparatus. It is the purpose of my paper, not to discuss the relative merits of these devices, but to call attention to a very simple attachment, known as the Beard-Mackie sight-indicator, which was designed three years ago, after a long series of experiments, by Prof. J. T. Beard, principal of the coal mining department of the International Correspondence Schools, Scranton, Pa., but formerly an active colliery-manager and engineer in the Western coal-field, and secretary of the Iowa State Mining Board. This little apparatus, which can be adapted and attached to any ordinary safety-lamp, is intended to utilize the familiar phenomenon of the lengthening of the flame-cap in proportion to the increase of methane in the surrounding atmosphere in such a manner as to measure the height of the cap with exactness, and to eliminate the element of guessing above mentioned, by substituting a plainly visible indication of the position of the flame-tip, whereby the percentage of gas in the air is made known.

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[2] *Transactions of the Institution of Mining Engineers*, vol. xxvi., p. 217.

This indicator has been successfully tested in practice both in this country and abroad.

The following description of the indicator was written at my request by Prof. Beard:—

The device depends upon the well-known property of platinum of inducing the union of oxygen and other gases in contact with its surface, which property is possessed by the compact metal to a less degree than spongy platinum only in proportion as its surface is less than the surface of the latter. The stimulation of the chemical activity at the surface of the metal, when gas is present, is sufficient to maintain a red heat in a platinum foil. This is shown by heating the foil to redness in a gas-flame, and then shutting off the gas suddenly and at once turning it on again. While the heat developed, in this case, is not sufficient to cause the gas to ignite, it maintains a red glow in the platinum, which only ceases when the gas is shut off. The degree of heating is determined by the ratio of the surface to the volume of the metal, which, in the case of spongy platinum, is sufficient to cause the ignition of the gas, and which, in the fine wires of the indicator, causes a white heat that enables the lamp to hold its flame, relighting the lamp after extinction in "sharp" gas. This feature, which is of great advantage in the work of testing for gas in the mine, has been often proved, both in the mine and in the laboratory, when the lamp has been introduced into an atmosphere of gas that was extinctive owing to the excess of gas. All flame would then die out within the lamp, the wires alone remaining incandescent, and relighting the gas when the lamp is slowly withdrawn, the gas in turn relighting the lamp. It is noteworthy that the platinum wires incandesce at a considerable height above the tip of the flame, owing to the peculiar property of the platinum that stimulates the combustion of the gas in contact with its surface.

The underlying principle of this device is practically the same as that involved in the Liveing indicator, described by Prof. Chesneau;[3] but in the Liveing indicator the original source of heat is an electric current made to pass through the platinum wire, while in the present device the heat is derived originally from the flame of the safety-lamp in which the indicator is placed.

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[3] *Trans.*, xxii., p. 139.

The same principle had been applied in a less practical manner, previously, by Mr. M. D. Mackie, an experienced fire-boss at the Marvine colliery of the Delaware and Hudson Railroad Company's coal department. Mr. Mackie supported a small platinum coil above the flame of a common Davy lamp by means of a brass rod that passed up through the oil-vessel into the lamp. By moving the rod up and down, a position was found in which the platinum-wire just ceased to glow. The height of the wire above the flame at the moment it ceased to glow furnished the means of telling the percentage of gas in the air fed into the lamp.

After seeing Mr. Mackie's lamp, and making a few preliminary experiments with wires of different gauge, I designed the present form of the sight-indicator; but not wishing to deprive Mr. Mackie of the credit that is his due, I have called it the Beard-Mackie sight-indicator.

The device, as shown in Fig. 1, detached from the lamp, consists of a ∩-shaped support, made of No. 14 brass wire and riveted to a brass disk, which forms its base and fits over the wick-tube of the lamp. The indicator is thus held firmly in position in the lamp by the same nipple that secures the burner. As shown in Fig. 1, supported on this frame, are seven platinum cross-wires, a straight standard-wire at the bottom, and above this, six percentage-wires, each having a small loop or circle in the middle. The loops enable the incandescent-wires to be more readily and quickly discerned within the gauze of the lamp. The lower standard-wire is for the purpose of gauging the height of the lamp-flame in pure air. The presence of gas is then made known by the incandescence of the successive percentage-wires, the percentage of gas being indicated at once by the number of wires aglow. The successive percentage-wires indicate, respectively, 0.5, 1, 1.5, 2, 2.5 and 3 per cent. of gas in the air.

In the calibration of the indicator an unbonneted Davy lamp, burning pure sperm oil, was used. The lamp was hung in a small wooden box 10 in. by 10 in. by 16 in., shown in Fig. 2. This box was connected below and above with a 10-in. pipe that formed a stack for the escape of the gas. The box was

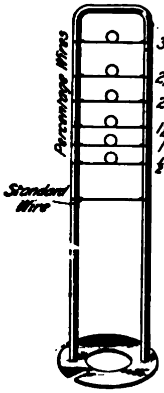

Fig. 1. — Wire-Frame Support for Platinum Wires.

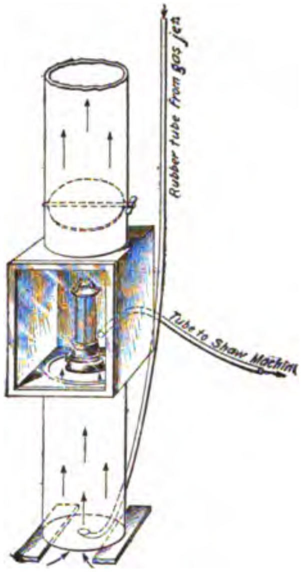

Fig. 2.—Box and Davy Lamp Used in Calibration.

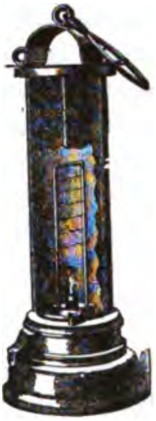

Fig. 3.—Sight-Indicator in a Davy Lamp.

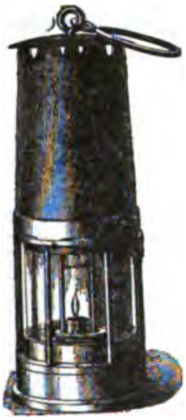

Fig. 4. — Sight-Indicator in a Bonneted Clanny Lamp.

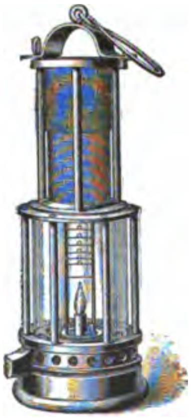

Fig. 5.—Beard's Special Form of the Clanny Lamp.

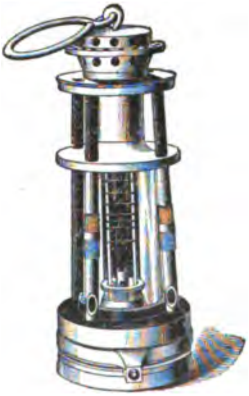

Fig. 6.—Special Form of the English Lamp Adapted for the Sight-Indicator.

provided with a glass door at the front, through which the behavior of the lamps could be distinctly observed; the pipe was open at the bottom and top to permit the free upward passage of the air and gas. City gas was used, and this was introduced into the lower end of the pipe by the rubber tube leading from a gas-jet above. A damper in the pipe, just above the box, allowed the operator to accumulate the gas so as to obtain any desired gaseous condition of the air passing through the box in a constant stream; and it was also possible to maintain this constant condition of the passing current for any length of time, so as to enable a test to be made with the Shaw gas-machine located at one side of the box. A rubber tube connected this machine with a short brass pipe inserted in the back of the box and extending to its center, terminating at a point close to the gauze where the feed-air entered the lamp. By this means, it was possible to obtain an accurate test of the air that was feeding the lamps at any desired moment.

Before placing an indicator in the lamp, experiments were made to ascertain the relation between the heights of the flame-cap and the percentages of gas causing the same, for the purpose of confirming the law formulated by Mr. William Galloway, which says that the height of the cap varies with the cube of the percentage of gas present in the air. The height (h) in inches, for any percentage (J), was thus found to be expressed by the formulas,

Unbonneted Davy (sperm oil), $J = \sqrt[3]{36\, h}$ (Beard);
Bonneted Davy (sperm oil), $J = \sqrt[3]{70\, h}$ (Galloway).

Having made these preliminary tests, an indicator-frame, with cross-wires of platinum arranged upon it at uniform distances apart, was placed in the lamp, and careful observations made to ascertain the relation of the height of incandescence of these wires to the percentage of gas in the air passing upward through the box. By this means, the heights of the several percentage-wires was determined. These observations and experiments, repeated many times and in different ways, revealed the discouraging fact that it was seemingly impracticable to attempt to insert a 0.5-per cent. wire, because its position was too close to the standard-wire used to gauge the flame. So close would this first percentage-wire be to the standard-wire that it required considerable care to set the flame so that it would incandesce the latter without causing both to glow. This difficulty, however, was successfully overcome later by using a slightly heavier iron wire in place of the platinum standard-wire. This iron wire had the effect of killing the heat in the immediate tip of the flame, with the result that each of the three lowest percentage-wires had to be raised. The lowest, or 0.5-per cent. wire, was raised the most; that next above, a less amount; and the upper one of the three, the least of all. The three upper percentage-wires were not disturbed in their position by the introduction of the iron wire for a standard-wire. The idea of thus killing the heat in the extreme tip of the flame was suggested by the principle of Sir Humphrey Davy's wire-gauze.

The iron standard-wire, however, proved a source of annoyance in the use of the indicator in strong gas. It would burn out in a short time, and required to be replaced by another wire. Further experiment showed that copper wire could not be used, probably owing to its high conductivity; aluminum, likewise, has a comparatively high conducting power, and, in addition, it would not stand the heat of the flame. Finally, the use of a platinum wire of a somewhat lower gauge was found to meet every requirement.

The advantage of the sight-indicator over the usual method of testing for gas may be briefly stated as follows: with the normal working-flame of a Davy or Clanny lamp, burning ordinary sperm or lard oil, it makes plainly visible within the lamp the slightest change in the gaseous condition of the mine-air, and indicates with great accuracy the exact percentage of gas present, in amounts varying from 0.5 to 3 per cent. Beyond this quantity the percentage of gas is estimated readily by the usual method of observing the height of the flame-cap, which is then clearly discernible. No time is lost in drawing down the flame when making a test, and the risk of losing the light is eliminated. The indicator, operating continuously and automatically, reveals the presence of unsuspected gas where a test by the usual method would be considered unnecessary; a possible accident may be thereby averted. Aside from the actual determination of the percentage of gas present, however, the chief advantage of such a device, in a mine, is its power to show constantly the fluctuation in the percentage of gas.

The test is quickly made, as the wires respond promptly to the slightest change in the gaseous condition of the air. A change caused by the accidental setting open of a door, and the consequent derangement of the ventilating current, or the liberation of gas by a fall of roof in another portion of the mine, or an increased outflow of gas from old workings, caused by a sudden fall of the barometer, or even an increased quantity of inflammable dust in the air, will at once be shown by this silent monitor, as has been proved in several instances in the mine. It is already reported as having been the direct means of saving men's lives by indicating an unsuspected increase of gas where it was not thought necessary to stop to make a test. This will be understood when it is remembered that the device gives its indication with the normal working-flame, the bright incandescence of the wires being clearly seen, notwithstanding the brightness of the lamp-flame. This is a great advantage over the flame-cap method, in which it is necessary first to stop and lower the flame of the lamp to a mere glimmer before making the test. In doing this, there is incurred not only the loss of time, but the risk of getting in the dark, which every miner rightly dreads.

The appreciation of the value of this device for the purpose named is shown by the fact that special lamps have been designed for its use in England and also in France, because the mining laws of these countries forbid the use of an unbonneted Davy lamp in a gaseous mine, and it was thought best to design a special lamp in each case. Fig. 3 shows the sight-indicator in a Davy lamp; Fig. 4 shows it in a bonneted Clanny lamp, in which, however, its sensitiveness is somewhat lowered by the effect of the bonnet, which also hides some of the upper wires. Special forms of the Clanny and Mueseler lamps, the former shown in Fig. 5, having a 3.5-in. glass, and admitting the air below the flame, have recently been designed by Mr. Beard, which give good results with the indicator. The special form of English lamp of the Ashworth-Hepplewhite-Gray type, designed for the indicator, is shown in Fig. 6.

POSTSCRIPT.—At the request of the Secretary of the Institute, the following information concerning the American and foreign patents of the Beard-Mackie indicator is here given:—

Country.	Number.	Date.
United States	692,885	Feb. 11, 1902.
	722,555	Mar. 10, 1903.
Canada	78,969	Jan. 13, 1903.
	81,663	June 30, 1903.
Great Britain	4,851	Feb. 26, 1902.
	20,281	Sept. 17, 1902.
Germany	171,891	Mar. 3, 1902.
	185,268	Sept. 20, 1902.
France	324.594	Sept. 18, 1902.
Belgium	165,669	Sept. 30, 1902.

SUBJECT TO REVISION.

[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

The Use of High Percentages of Fine Ore in a Charcoal Blast-Furnace.

A Discussion of Mr. Hall's paper, read at the Washington Meeting, February, 1905.

R. H. **Sweetser**, Sault Ste. Marie, Ont. (communication to the Secretary*):—The recent work of furnace No. 1 of The Algoma Steel Co., at Sault Ste. Marie, Ontario, using for fuel, first all charcoal, then a mixture of charcoal and coke, and finally all coke, upsets the estimates given by Mr. Hall in the last two paragraphs of his interesting paper. Furnace No. 1 was built for a charcoal-furnace, and it was run on charcoal fuel from March 6 until July 9, 1905; then, for a week, a mixture of charcoal and coke was used, and, since then, coke alone has been the only fuel.

It is to be regretted that at no time, during the run on charcoal, was there enough charcoal on hand and "in sight" to warrant blowing the furnace as hard as it should have been blown. During April and May the supply of charcoal limited the amount of blast to about 8,000 cu. ft. of air per min.; in June, to about 8,900 cubic feet. For a few days in July about 10,000 cu. ft. were blown, and then the maximum daily output, 173 tons (2,240 lb.), was reached. At all times the quality of the charcoal was poor, having been made from wood cut from three to four years before. Doubtless this furnace could have produced 200 tons of iron per day, even with this quality of charcoal, provided the supply had been sufficient; and with good charcoal I see no reason why it could not make as much iron per day as it has made with coke.

During the one week of using a mixture of charcoal and coke, the changes in quantity of blast and composition of the slag followed each other so closely that no single condition could last long on the furnace. The results were good, and the pig-iron was about the same in quality as that made during the best week with charcoal alone. The maximum daily output was 175 tons of standard Bessemer pig-iron.

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* Received October 31, 1905.

Since July 16, 1905, the coke has been used exclusively and the supply has been plentiful. Because coke requires at least 50 per cent. more air than charcoal does, the quantity of blast has been much increased, and the furnace has been blown nearly to its limit. During September, the quantity of blast was about 19,600 cu. ft. per min., as measured by piston-displacement. The average composition of the pig-iron for the month was, silicon 1.64 and sulphur 0.032 per cent. The maximum daily output was 218 tons; the three best daily averages, for periods of one week each, were 196, 198 and 203 tons respectively. The daily average from September 1–15 was 190 tons. These figures agree fairly well with Mr. Hall's estimate for the product of a charcoal-furnace having a hearth 8.5 ft. in diameter (furnace No 1 is 70 ft. by 13.5 ft. by 8.5 hearth); yet this quantity is made in a coke-furnace.

According to Mr. Hall's estimate, it is doubtful if this same furnace could make from 25 to 33 per cent. more charcoal-iron than it has made coke-iron, since this would mean a daily product of from 240 to 260 tons, and a maximum of from 270 to 290 tons. The cubic capacity of the furnace is only 6,119 cu. ft., and, while making 200 tons per day, the stock passes through in less than six hours. Still, it would take only about 16,000 cu. ft. of blast per min. to make 260 tons of charcoal-iron, and the amount now used on coke is 19,000 cubic feet. Therefore, the results obtained at Sault Ste. Marie show that either one or the other of Mr. Hall's estimates should be modified; also that the largest charcoal-furnace in the world has been so constructed that it has given excellent results with either charcoal or coke.

SUBJECT TO REVISION.

[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

The Mojave Mining District of California.

BY CHARLES E. W. BATESON, NEW YORK CITY.

(Bethlehem Meeting, February, 1906.)

I. LOCATION.

THE Mojave mining district is situated in a group of small hills centering around Soledad peak, in the Mojave desert, Kern county, Cal. These hills are about 4.5 miles SSW. of Mojave, a railroad town at the junction of the Santa Fé and Southern Pacific railroads.

The town of Mojave is about 50 miles north of Los Angeles, to which it is connected both by telegraph and by rail. The distance on the Southern Pacific railroad is 102 miles, covered in 3 hr. and 45 min. by express train. A sketch-map of this region is shown in Fig. 1.

The Mojave district is relatively isolated. The only other mining towns in this section of California are Randsburg and Johannesburg, in a district (containing the well-known Yellow Aster mine) at the northern end of a low ridge of hills, which begins about 20 miles NE. of Mojave, runs nearly N. for 35 miles, and varies in width between 3 and 6 miles. As will be seen later, the origin and formation of these hills are not the same as those of Soledad peak.

II. CLIMATE AND VEGETATION.

The climate and vegetation of the Mojave district are typical of the arid regions of the southwestern United States. During the winter and spring there is some rainfall, and the temperature is generally from 60° to 70° F. in the day-time. The rainfall in the spring is often very considerable for short spaces of time, and cloud-bursts are not infrequent. In summer there is continual sunshine, with temperatures, as a rule, exceeding 100° F. in the day-time, while 115° F. in the shade of a house is not at all unusual; but at night the temperature falls considerably. No rain falls during the summer. The vegetation consists of very little desert grass, a little grease wood, sage bush and a few yucca trees.

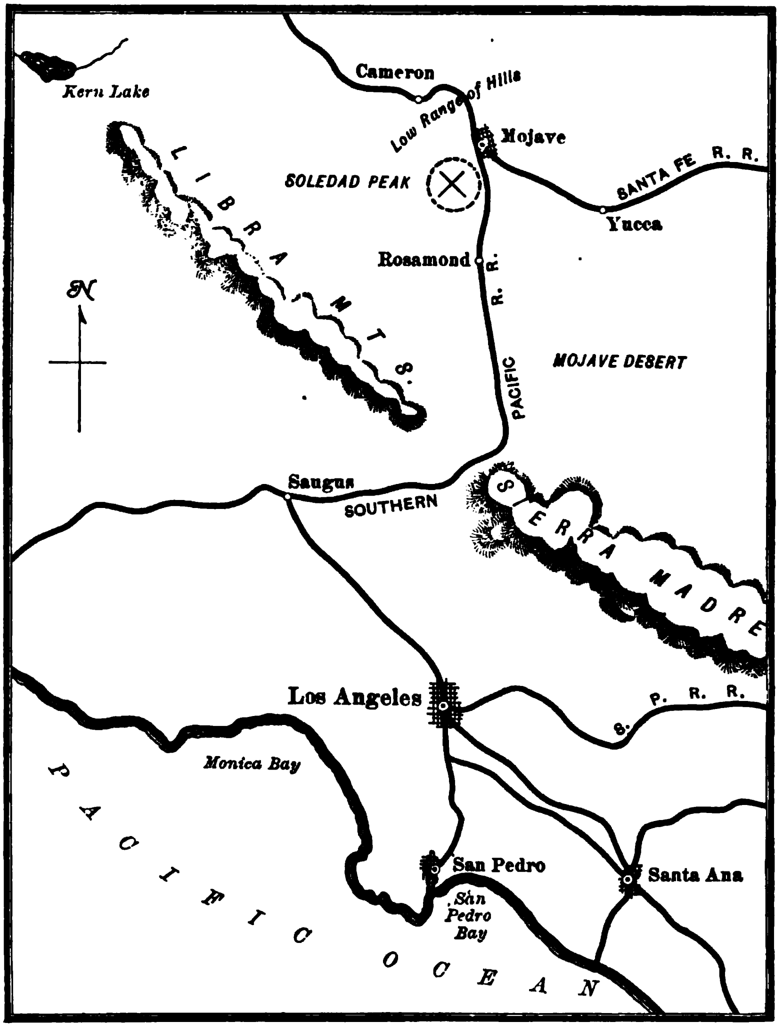

FIG. 1.—SKETCH-MAP OF SOUTHERN PART OF CALIFORNIA, THE CIRCLE SHOWING POSITION OF SOLEDAD PEAK.

III. TOPOGRAPHY.

The topography presents low ranges of hills and isolated peaks of igneous or volcanic origin, which seldom rise more than from 1,500 to 2,000 ft. above the level of the desert. The valleys, which are of much greater area than the hills, are the typical waste-filled interior basins characteristic of the desert.

In early geological history, the valleys were deeper and the hills higher than they are now. The hills and ridges, being of igneous origin, were particularly susceptible to rapid disintegration, because the comparatively great change in temperature between day and night caused appreciable expansion and contraction in the outer crust of the rock, and the unequal rate of expansion and contraction of its constituent minerals produced stresses under which the rock-surface cracked and peeled off. The detritus, before any great amount of it could accumulate, was carried by the heavy rains into the gorges, where the water collected in great volume and swept it out into the valleys. This action exposed a fresh surface of the rock, to undergo the same cycle of disintegration.

The detritus was deposited at the mouth of the gorges as large alluvial fans, which increased in size until they met and merged into one another, forming detrital slopes. These slopes, as they extend outward and met the detrital slopes of adjacent ridges, formed detrital plains, which continued to grow until they completely filled the interior basin, and even overflowed it.

But little material, however, is carried out of these basins unless it be in solution. The water from the gorges soon loses itself in the coarse waste of the fans and plains, and does not reappear again, except, perhaps, when there has been a very heavy or extensive downpour, in which case it issues as innumerable springs at the head of a "crossing," *i.e.*, a gorge that connects one waste-filled valley with another.

The mouth of a crossing is shown in Fig. 2. The little hills, composed of bright red and white sandstone, are local and are sedimentary, while the surrounding hills are igneous. The age of these sediments I could not determine. The crossing is about 3 miles long. Water can be obtained in these crossings, even in the driest seasons, by digging a short distance, sometimes only a few feet; and also, in many cases, by digging at some distance from the mouth of a gorge that comes from the hills, especially if it be a main gorge, having branches and a pretty large steep cone at its mouth.

The permeability of the waste-filled valleys does not allow the water to go far on the surface, so that its burden, as it comes from the hills, is entirely deposited on the alluvial fans. Subsequent rains move this deposit farther and farther out until the line where two slope-plains meet is encountered, at which place the finer material is worked down towards the mouth of a crossing, so that the waste-filled valleys slope upward in every direction from the head of a crossing. The mouth of a crossing may or may not be one of the highest points in the waste valley into which it disgorges, but the general level of the valley from which it comes is higher than that of the valley into which it runs.

Considering the local topography of the Mojave district, Soledad peak is a mass of eruptive rocks, whose highest and most northerly point, Soledad peak, is about 4,000 ft. above sea-level and about 1,250 ft. above the general level of the surrounding desert. Mojave and Rosamond stations, on the desert, are 2,751 and 2,315 ft. above sea-level respectively.

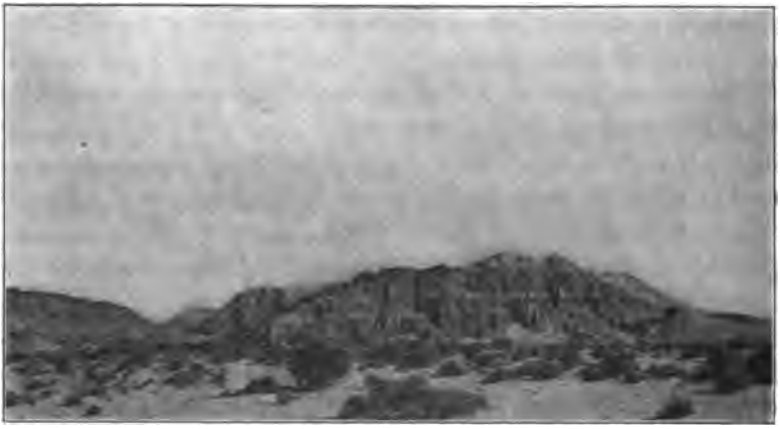

FIG. 2.—MOUTH OF A "CROSSING" IN THE MOJAVE DESERT.

A considerable number of much smaller hills are grouped south of Soledad peak, of which the miners consider them as "spurs."

The map, Fig. 3, shows the generally circular to oval contours of all these hills.

Bowers hill, the only small one with a name, rises about 400 ft. above the desert, about a quarter of a mile northeasterly from Soledad peak, and is less than a mile long.

IV. Rocks.

Five varieties of igneous rock appear in the district.

1. *Granite.*—This is the oldest formation exposed, and probably underlies the entire district. It shows at the surface along the northeast flank of Bowers hill. It dips to the southwest and does not re-appear in the mineralized zone. It does show,

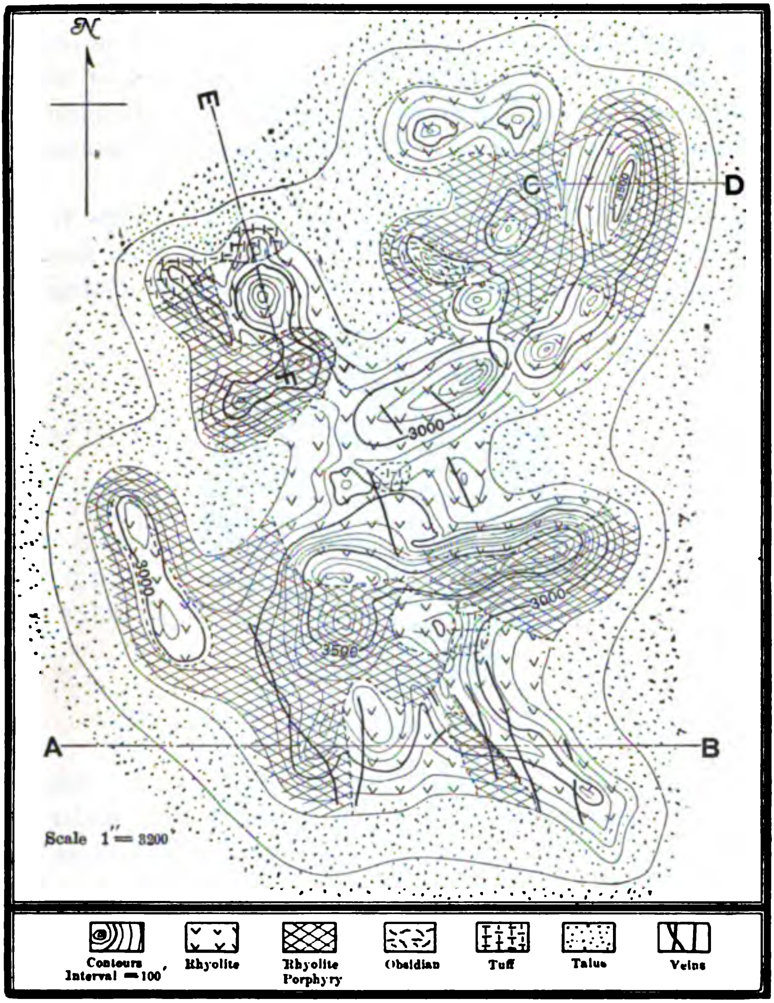

Fig. 3.—Topographical and Geological Map of the Mojave District, Kern County, Cal.

however, about 5 miles SSW. of Soledad peak, where it underlies some low hills of tuff.

Hand-specimens of this granite show a coarse-grained quartz-orthoclase-albite rock, containing a very small quantity of biotite.

2. *Rhyolite-Porphyry.*—This rock, lying upon and in contact with the granite, has by far the greatest exposure of all the rocks of the district, as shown in Fig. 3, and is the most important by reason of its quantity and because it is the country-rock of the veins.

Both in hand-specimens and under the microscope it presents a much decomposed appearance. Quartz, often showing a decidedly hexagonal outline, is the only mineral distinguishable to the naked eye. In hand-specimens the rhyolite-porphyry is nearly or quite white. In thin sections under the microscope the rock is seen to be very extensively altered, as shown in Fig. 4. Because of the complete obliteration of all traces of structure, quartz is the only original mineral recognizable. Quartz occurs, also, in considerable amount as a secondary mineral. Kaolin, showing slightly developed spheroidal structure, is present in large quantity. Secondary calcite is probably present, but in no place is it developed sufficiently to be identified. Neither in hand-specimens nor in thin sections does the rhyolite-porphyry show lines of flow.

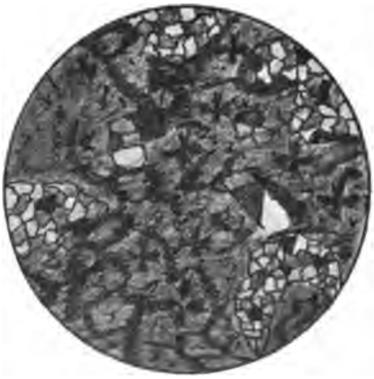

FIG. 4.—RHYOLITE-PORPHYRY GREATLY ALTERED.

3. *Rhyolite.*—This rock, in sheets and patches, overlies the rhyolite-porphyry and forms the summits of many of the hills,

as shown in Fig. 3. A few veins outcrop in the rhyolite, but they have not been developed even slightly.

In hand-specimens the rhyolite is dirty brown in color, and greatly resembles devitrified obsidian, having strongly marked flow-lines. In thin sections under the microscope, as shown in Fig. 5, it is seen to be very much decomposed and similar to the rhyolite-porphyry. Quartz, the only recognizable mineral, is both primary and secondary. In many cases the secondary quartz has replaced feldspar crystals, molecule by molecule; and in one case (the crystal near the center of Fig. 5) it has even preserved the optical property of orientation of an orthoclase twin crystal. No other mineral is recognizable.

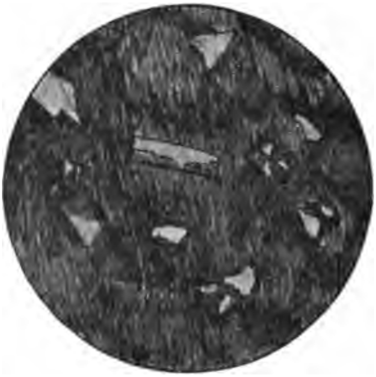

FIG. 5.—RHYOLITE GREATLY ALTERED, SHOWING ORTHOCLASE TWIN CRYSTAL REPLACED BY QUARTZ.

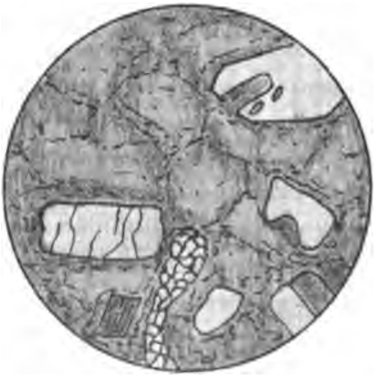

FIG. 6.—RHYOLITE, SHOWING LINES OF FLOW.

Fig. 6 shows a thin section of a nearly fresh specimen of this rhyolite. In hand-specimens it is almost white, of fine texture, and shows faint flow-lines. In the thin sections it is seen to be a devitrified rhyolite, showing phenocrysts of orthoclase, biotite and quartz. The biotite and orthoclase have no unusual features, and the quartz occurs both primary and secondary. The primary quartz originally had well-marked crystal outlines that later became indistinct in most of the crystals through re-absorption of the silica; while, in others, it remained fairly well preserved. The secondary quartz is in minute, interlocking pieces of no crystal outline and of varying orientation.

4. *Obsidian.*—In hand-specimens the obsidian is black in color and full of small holes, about an eighth of an inch in diameter. Thin sections are nearly opaque, and show nothing except that it is greatly devitrified. It is probably a more quickly-chilled part of the rhyolite, and not a distinct flow. It occurs only in one place, as a capping to one of the smaller hills, and is underlain by the rhyolite-porphyry described above, and shown in Fig. 3.

5. *Tuff.*—The tuff, composed of volcanic ash, is now so much decomposed that very little can be made of its mineralogical character except that quartz, and, at rare intervals, a fragment of feldspar are recognizable. In hand-specimens it generally varies from a dirty white to a pale, greenish color, and appears rather fine textured for a tuff. It occurs in three small patches, overlying the rhyolite in two cases, while in the the third it seems to overlie a contact between the rhyolite and the rhyolite-porphyry. Its actual contact was not seen on the rhyolite-porphyry, being covered by the talus, although it was seen on the rhyolite. The map, Fig. 3, shows it resting in part on the rhyolite-porphyry, because outcrops of the rhyolite-porphyry came very near it, and there was no intermediate talus of rhyolite. The detritus and waste of the hills are shown in Fig. 3 as surrounding them.

V. ORIGIN OF THE ROCKS.

There are two tenable hypotheses in regard to the relation between the rhyolite-porphyry and the rhyolite.

1. According to the first, the rhyolite is the outside quickly-chilled portion, and the rhyolite-porphyry is the more slowly-cooled portion of a volcanic outburst.

2. According to the second, there have been several erup-

tions, at least two of which are observable. Of these, the first produced the rhyolite-porphyry (which may or may not have been finer grained on its surface), and was followed by a period of quiescence, during which considerable erosion took place, and after which the second eruption produced the rhyolite, and, in its expiring stages, the volcanic tuffs.

The evidences to support the first view (that of a single flow) are:—

In several places the rhyolite grades from a rock which resembles the obsidian, shown in Fig. 5, having the same dirty brown color, into a nearly porphyritic rock almost white in color, shown in Fig. 3. Then, after an interval of from 150 to 200 ft. covered by talus, the typical rhyolite-porphyry appears. At no place was I able to find exposed a continuous gradation of one into the other. The mineralogical characters of the rock serve in a way to support this view. Both the typical rhyolite, shown in Fig. 5, and the typical rhyolite-porphyry, shown in Fig. 4, are too greatly decomposed to give clear evidence, and the only satisfactory thin sections, shown in Fig. 6, came from a rock that is almost porphyritic in texture, and is clearly a part of the rhyolite.

In favor of the second hypothesis; namely, that there were two separate and distinct flows, the following facts may be regarded as evidence:—

In one spot, on the Echo claim, a direct contact was found where the rhyolite-porphyry is typically developed, as is also the rhyolite. The rhyolite-porphyry occurs as a small circular outcrop, about 2 ft. in diameter, which is entirely surrounded by a breccia, from 1.5 to 3 in. thick, colored brown and containing a great deal of quartz, followed by the rhyolite. I think that the presence of the breccia precludes this outcrop from being a boulder that had become imbedded in the rhyolite. But whether this is a boulder or rock in place it is unimportant, since in either case it shows that the rhyolite-porphyry is older than the rhyolite.

One of the smaller hills was capped with rhyolite in the form of black obsidian, below which all outcrops were concealed by talus until near the base, where rhyolite-porphyry was exposed. These two rocks, the rhyolite and the rhyolite-porphyry, were sharply contrasted and could easily be distinguished. The talus, however, contained only the typical examples of each, there being no transition-forms. From this occurrence the inference was reached that they represented distinct and separate outbreaks.

The dome-like shape of the hills, with the rhyolite as a cap, shown in Fig. 3, seem to indicate that a cone of this harder, more-resistant rock came up through the rhyolite-porphyry in necks and overflowed on the surface, and that these necks have resisted weathering better than the more easily disintegrable rhyolite-porphyry. The mineralogical characteristics of the rocks, however, do not strongly support this hypothesis. Practically all that can be said is that the primary quartz in the rhyolite generally shows considerable re-absorption, while that of the rhyolite-porphyry does not; moreover, the rhyolite shows flow-lines, which are not observed in the rhyolite-porphyry. The mineralogical characters of the rocks would, in either hypothesis, be very similar, since the magmas were in all probability identical, being doubtless derived from the underlying granite. Hence, the relationships in the field are the strongest and most trustworthy evidence, and they indicate, with a high degree of probability, two flows. These relationships are illustrated by Fig. 7.

That the Mojave district is an isolated one, and that the origin of all the desert hills is not the same, or even due to similar causes, is shown by contrasts presented in the Randsburg-Johannesburg area. That district, as already observed, occupies the northern end of a long, low ridge rising from 1,000 to 1,500 ft. above the general level of the surrounding desert. The back-bone of the ridge is diorite, which is flanked on both sides by heavy beds of metamorphosed hornblende schist, dipping in places as much as 45° away from the center or axis of folding.[1]

VI. VEINS.

Almost all the veins now known are on the northern flank of Soledad peak, and their strike is generally a little south of west, as is illustrated in Fig. 3. The principal and largest veins are operated by four companies. Beginning at the west, the Echo Mining Co. works the Echo, Grey Eagle and Starlight veins; about 0.5 mile farther east the Queen Esther Mining Co. works the Queen Esther vein; and next to the Queen Esther is the Karma Mining Co., working the Karma vein.

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[1] *13th Report of the State Geologist of California* (1895–96).

The Exposed Treasure vein on Bowers hill is worked by the Treasure Mining Co., a New York concern.

The Echo vein has the normal strike and dips to the northeast, as shown by Fig. 7. Its outcrop can be traced for 1,800 ft., and throughout its entire length a rather constant width of about 3 ft. is preserved. This general width also persists in depth as far as the vein is known—something over 200 feet. The gangue, or vein-filling, is quartz of the variety generally known as "sugary." In general the line of demarcation between the quartz-filling and the country-rock is sharp, although in places the walls seem to be much shattered for a few feet on each side of the vein, the

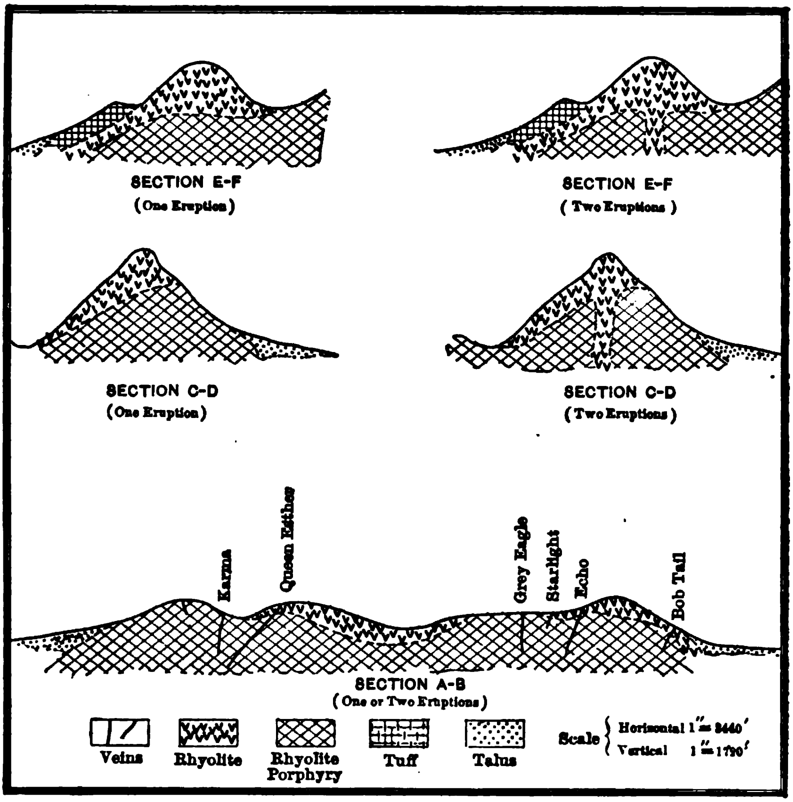


FIG. 7.—SECTIONS OF PORTIONS OF THE MOJAVE DISTRICT, SHOWN IN FIG. 3, ILLUSTRATING THE PROBABLE RELATIONSHIPS.

quartz having filled any spaces and cracks that were formed. No gouge-seams, slickensides or other evidences of extensive movement after the quartz-filling had been introduced were observed. In places next to the country-rock, and even in the quartz itself, patches of kaolin are found. The wall-rock is silicified rhyolite-porphyry, which is very hard and difficult to mine. The values are in gold and silver. The gold occurs free in very minute scales associated with pyrite. Along the outcrop and near the surface the gold is almost all free. The silver occurs as horn silver (cerargyrite) in small specks along and near the outcrop, changing to argentite in depth. The entire vein is mineralized to some extent. The workable portions, however, occur in irregular bunches, which may have considerable dimensions, both in length and depth; that is, from 100 to 200 feet.

The Starlight vein, distant about 300 ft. east of the Echo, is parallel to it in strike, and dips to the northeast. Its outcrop cannot be traced for the entire distance. Its average width is about 3 feet. The vein-filling, the relationship between the vein and the wall-rock and the mineralization, are the same as in the Echo. The major part of the value is in silver.

The Grey Eagle vein commences near the northern end of the Starlight and diverges from it in a southerly direction, until about 100 ft. or more from it, and then turns parallel to it. In general the dip is 90°, from which, however, it varies, sometimes to one side and sometimes to the other. The vein connects with the Starlight at increasing depths towards the south. Its average width is a little less than 3 feet. The vein-filling, and the relationship of vein to the wall-rock and the mineralization, are the same as the Echo and Starlight, except that the gold value is greater than that of the silver. At the one place developed, where the two veins join, shown in Fig. 8, considerable kaolin occurs, and the values are not so high as on either side of the connection. The quartz-filling, however, shows no discontinuity in passing from above the connection to below it.

The mine-management believes that the Grey Eagle crosses the Starlight vein, basing the belief on a small length of outcrop found to the west of the Starlight vein, having a strike nearly the same as that of the Starlight vein, and being in a general line with that part of the Grey Eagle vein which joins

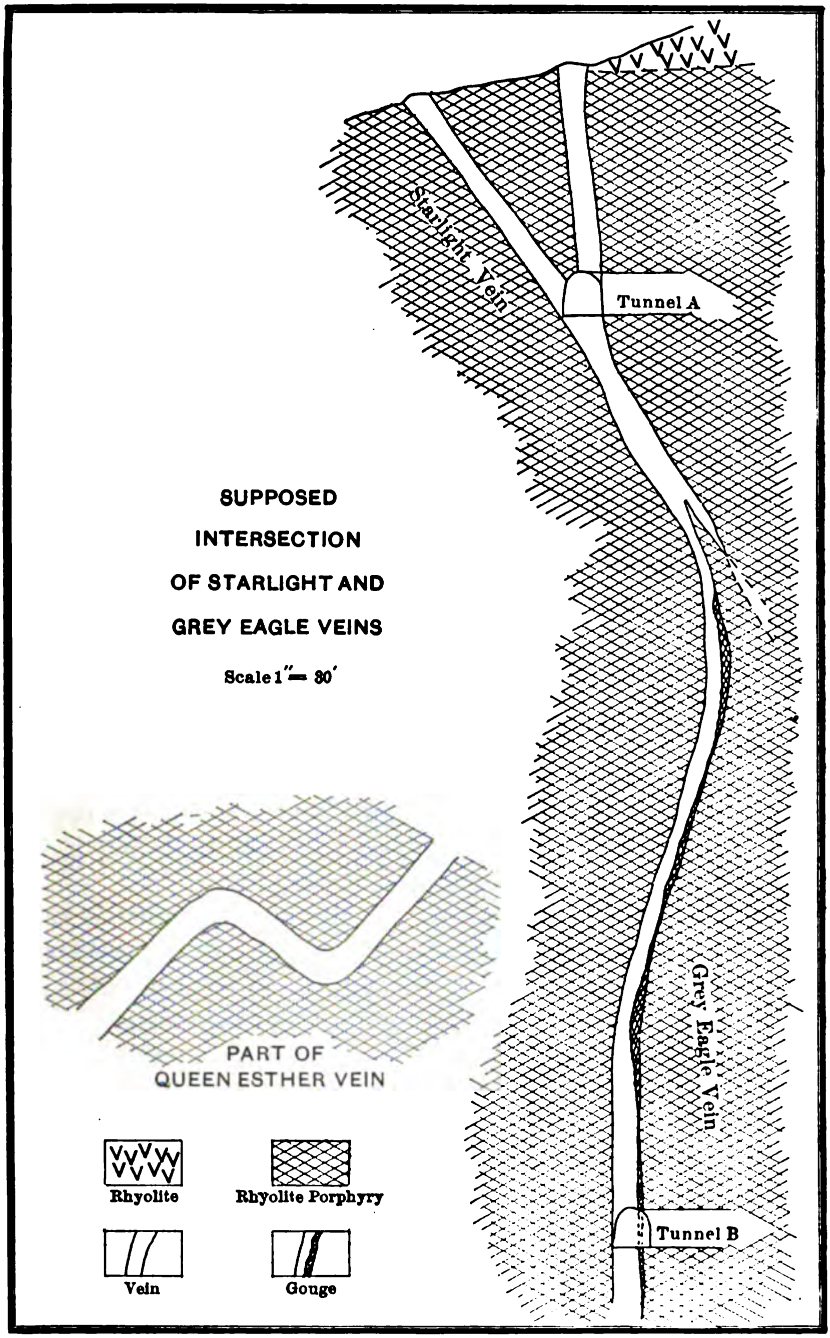


FIG. 8.—SECTIONS OF STARLIGHT, GREY EAGLE AND QUEEN ESTHER VEINS.

on the outcrop. It is believed that the Starlight has faulted the Grey Eagle.

The Queen Esther vein runs more nearly north and south than any of the others. It dips about 60° to the east. The vein-filling is sugary quartz. The country-rock is greatly decomposed rhyolite-porphyry. The mineralization is similar to the Echo. The width of this vein is generally from 5 to 6 ft., but it varies a great deal, in some places being nearly 12 ft., while in others it is only about 3 feet. A remarkable feature of this vein is the rolls that it takes as it gains in depth. This is shown in Fig. 8. At the present stage of development three of these rolls or folds are known. The first one encountered in depth is the smallest, and the third the largest. They dip along the vein about 10° to the north. The largest one displaces the vein 30 ft. horizontally and 10 ft. vertically.

The Karma vein, dipping about 85° to the east, has the prevailing strike of a little south of west. Its outcrop can be traced continuously for about 1,000 feet. It varies in width from 2 to 5 ft., although, in places, the mineralized zone reaches considerable width. In the case of the "glory hole," it is about 40 ft. to the vein-stuff, which fills cracks and fissures extending into the country-rock on both sides of the vein proper. At one place on the outcrop, about 200 ft. in length, this vein, together with the numerous small branches it there possesses, reaches a width of between 60 and 80 ft., but it is reported not to be well-mineralized at this point.

The gangue is sugary quartz, and the mineralization is the same as that described above. Bromyrite was reported to have been abundant in one of the stopes, now worked out. A small piece of quartz, still adhering to one of the walls, was obtained, showing small specks of the reported bromyrite. On careful investigation (the specimen was so small that entirely satisfactory results were impossible) the green specks were found to be in all probability copper stains, and not bromyrite at all. The character of this mineral as determined are:—color, dark green; luster, dull; hardness, from 4 to 5; opaque, even under the microscope. Very rich ore was obtained from this slope. The country-rock of this vein is rhyolite-porphyry.

The Exposed Treasure vein is on Bowers hill. I did not examine this vein, but from hearsay I present the following:—

The vein maintains the usual strike of all the veins of the district, but departs from the rule by dipping to the west. The wall-rock for a distance is rhyolite-porphyry, and then the vein follows the contact between the granite and the rhyolite-porphyry. The mineralization follows the general rule, and the pay ore is very rich but extremely irregular.

A small vein on the southwestern flank of Soledad peak, thought in all probability to be an extension of the Starlight, see Fig. 3, is interesting, because its wall-rock, see Fig. 9, shows a double brecciation. It also shows pyrite in the cementing material of the second brecciation. The first cementing material was mainly kaolin, with some secondary quartz. The second cement comprised secondary quartz and considerable kaolin, and with pyrite in places, which carries considerable gold.

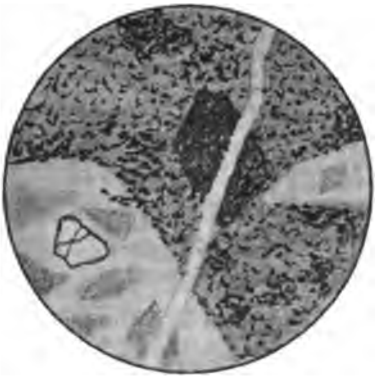


FIG. 9.—SECTION OF WALL-ROCK OF VEIN ON SOLEDAD PEAK, THOUGHT TO BE A CONTINUATION OF THE STARLIGHT VEIN.

Whatever the history of the volcanic action may have been, it is quite evident that the veins did not appear until all volcanic action was over.

Almost all the known veins are on the northern flank of the group of hills, and these are easily divisible into two main groups:—one, the Echo group, to the west; and the other, the Queen Esther-Karma group, to the east. The exposed Treasure and others, perhaps not yet found, make a third but less important group on Bowers hill. The general course of all these veins is a little west of north.

Both of the first two groups seem to have a focus where all of the veins in each group will meet, provided they preserve their present dip. In the Echo group, this focus is about 700 ft. below the general level of the desert, and in the Queen Esther-Karma group it is from 400 to 500 feet..

All these veins are typical quartz-veins containing quartz and minerals derived from the decomposition or alteration of the country-rock and deposited in fissures, which are caused by contraction on cooling; in this case the cooling has been from fusion. In some of the veins the brecciation of the wall-rock is clearly observable, and in one case a double breccia—a brecciated breccia—is shown.

In the Queen Esther vein rather remarkable rolls are found, which were not caused by any cross-fissures or faults, so far as could be observed, but were probably due to the original fissuring of the rock-mass by cooling, which has since remained undisturbed; that is, no vertical movement of the walls has taken place.

From the above description it appears that the fissures were originally formed by cooling, followed, in some cases, by slight movements of the rocks which caused the production of breccia by the attrition of the walls over each other. This result has happened in one observed case at least twice. In other cases there was no movement whatever, and in no case observed did the movement amount to more than a few inches. Accurate observation concerning the amount of movement in volcanic rocks, especially if they have been badly altered by decomposition, is extremely difficult, if not impossible, to detect.

A movement of only a few inches, or at most a few feet, is inferred here because there has clearly been no movement in some of the veins; and while there is brecciation of the walls in other veins, there is not enough variation in the width of any one of them to indicate extensive movement.

The quartz-filling of the veins and the silicification of the walls certainly did not take place until all movement had ceased, and since then there has been little or no movement, so far as has yet been recorded.

In one or two veins there is a little gouge occuring irregularly on one or the other of the walls, which indicate some slight movement of that wall. This gouge is nearly pure kaolin, and in no observed locality did it cross the vein of quartz to the other wall; moreover, it was not great in amount; hence, at best, the movement was only a slight one. The Starlight-Grey Eagle junction may or may not be a cross-fissure. If it is, the fissuring was previous to the filling of the vein. The values are gold and silver. The gold occurs native in minute specks, and to a small extent in pyrite. The silver occurs mainly as a black sulphide, argentite, with cerargyrite in small grains sparingly disseminated in places near the outcrops. The values are not at all regularly distributed, but occur in irregular patches of no definite outline, and which vary in size up to a few hundred feet along the vein to a hundred or more in depth. The width of the veins varies from a few feet up to 12 feet. Mineralized zones occur, however, of much greater width.

VII. SUMMARY.

The Mojave district is of volcanic origin, and has been formed by two eruptions, the first of quartz-porphyry and the second of rhyolite. The underlying country-rock is granite. After all volcanic action had ceased, fissuring took place, followed by deposition, from a rising solution, of the quartz with the gold- and silver-minerals, thus forming the veins.

The eruptives are very greatly altered, so much so that, with few exceptions, their original minerals are altered beyond recognition. The general form of alteration—the original minerals being quartz, orthoclase, some other feldspar, probably albite and biotite, with pyrite and perhaps some other minerals as accessories—is that which is typical of the belt of weathering in arid regions; namely:—

1. The feldspar was altered to kaolin and quartz, with the loss of potassium, calcium or sodium, as the case may be.
2. The original quartz remained as such.
3. The biotite was altered to kaolin with the probable formation of serpentine and gibbsite, although no gibbsite was observed.
4. The pyrite, gold- and silver-minerals went through the orthodox cycle of changes. The values in the early history of the veins probably were very evenly distributed.

Since the formation of the veins, however, considerable erosion has taken place, with the consequent lowering of the outcrop and also of the water-level. Secondary enrichment has taken place in portions of the vein by the well-known phenomena of downward concentration, caused by the leaching of the values from the upper portion of the vein, and their deposition at a lower level, at or near the ground-water level.

No mine, with the possible exception of the one on Bowers hill, has reached the ground-water level, so nothing can be said of the veins below it, or how much further it will be necessary to sink in order to reach it.

There is no reason why the mineralization of the veins should not continue into the granite, since in this district the wall-rocks, being of a like, if not identical, chemical composition, and varying only in the degree of their crystallization, possession or non-possession of flow-lines, etc., can have had no differential effects on the deposition of the ores in different parts of the vein. The portions enriched by downward concentration, which, at present, form the pay portions of the veins, can certainly be expected to end when the ground-water level is reached. Whether it will pay to work the veins below the level—at present unknown—is a problem which can only be solved by actual trial.

SUBJECT TO REVISION.

[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

Fine Grinding of Ore by Tube-Mills, and Cyaniding at El Oro, Mexico.

BY G. CAETANI, ROME, ITALY, AND E. BURT, EL ORO, MEXICO.

(Bethlehem Meeting, February, 1906.)

CONTENTS.

PAGE
I. INTRODUCTION, ... 84
II. EL ORO MINE, ... 85
III. OUTLINE OF ORE-TREATMENT, ... 85
  1. Mills and Cyanide-Plants, ... 85
  2. Classification of Mill-Products, ... 88
IV. RELATION BETWEEN DIAMETER OF SAND-GRAIN AND EXTRACTION, . 89
V. SAND-INDEX, ... 93
VI. TUBE-MILLS, ... 95
  1. Grinding-Efficiency, ... 97
  2. Pebble-Consumption, ... 102
  3. Liners, ... 103
  4. Cost of Grinding, ... 103
VII. SLIME-TREATMENT, ... 104
  1. Preliminary Test No. 1, ... 106
  2. Preliminary Test No. 2, ... 109
  3. First Modification of Slime-Treatment, ... 110
  4. Modified Slime-Treatment, ... 112
VIII. SAND-TREATMENT—MILL No. 2, ... 117
  1. First Preliminary Test, ... 118
    a. Gold- and Silver-Values, ... 119
    b. Values of Drained Solution, ... 120
    c. Cyanide Solution, ... 120
    d. Conclusion, ... 120
  2. Second Preliminary Test, ... 121
  3. Modified Treatment, ... 124
IX. PRECIPITATION, ... 127
  1. Zinc-Room, ... 127
  2. Precipitating the Solutions, ... 128
  3. Clean-up, ... 129
  4. Screened and Acid Precipitates, ... 131
  5. Briquetting the Precipitates, ... 132
  6. Melting, ... 133
  7. Slags, ... 133
  8. Cutting the Zinc, ... 134
  9. Cost, ... 134

I. INTRODUCTION.

WE owe to the courtesy of Mr. R. M. Raymond, Manager of the El Oro Mining & Railway Co., Ltd., the permission of publishing in this paper the results of a series of experiments and tests made in view of determining the economical limit to which the fine grinding of the ore by tube-mills could be carried on.

For the sake of clearness, the following definitions are given of certain terms used in this paper, as well as of the units and screens in the experiments.

Slime: In a general way "slime" is that mill-product, of which from 90 to 95 per cent. will pass a 200-mesh screen (0.067 mm. aperture), and which is treated as one class of material in the El Oro cyanide-plants. As a screen-product, slime constitutes all material that will pass a 200-mesh screen.

In sizing, the following products are distinguished:—

Coarse Sand: That material remaining on a 100-mesh (0.111 mm. aperture) screen.

Fine Sand: That passing through 100-mesh and remaining on a 200-mesh (0.067 mm. aperture) screen.

Slime: That passing through 200-mesh. *Fines,* which pass through 200-mesh and settle in 30 seconds, and *silt,* which does not settle in 1 minute.

Sand-index: The number proportional to its total fineness considered from the economical point of view, as explained on page 93.

Absolute extraction: The percentage of values actually brought into solution.

Actual extraction: The percentage of values actually brought to the zinc-boxes.

Units: Dollars, U. S. Currency; pounds; and short tons (2,000 lb.). Gold is valued at $20.67, and silver at $0.50 per ounce.

Screens: In the sizing-tests the screens used were:—

Mesh (per 1 in.), .	24	30	40	60	80	100	150	200	250
Aperture (mm.), .	0.740	0.515	0.424	0.250	0.159	0.111	0.090	0.067	0.058

Strengths of solution: Strengths are expressed in the percentage of KCN contained, though the sodium cyanide, which is used exclusively at El Oro, corresponds to 125 per cent. of KCN.

II. The El Oro Mine.

The El Oro Mining & Railway Co., Ltd., operates a mine at El Oro, in the State of Mexico, about 100 miles NW. from the City of Mexico. The ore is gold-bearing quartz, containing a small amount of silver, and occurs in large ore-bodies in slate. The whole vein-bearing formation has been covered by a heavy andesite flow, in places several hundred feet thick; and, therefore, seldom do the veins outcrop. The principal vein is the "San Rafael," which strikes N. 10° W. and dips 63° towards the west. This vein averages 50 ft. in width, and has been followed for more than a mile in length.

1. *The Ore.*—The ore, so far worked in the El Oro mine, is quite oxidized, and only a small amount of pyrite is met with at the present depth of the mine. The ore is treated by amalgamation on plates in the stamp-mill, and the tailings from these are cyanided.

The oxidized ore, a very hard, compact quartz, averages in value from $6 to $15 gold, and from 3 to 5 oz. of silver per ton.

The quartz has been deposited by aqueous solutions, and, in places, show a distinctly banded or wavy structure.

The gold and silver are scattered through the quartz in a remarkably fine state of division and, locally, in a very uniform way. Probably all the gold is native, and part of it is in the form of "rusty gold;" but it is so finely divided that seldom can "colors" be detected. The ore, crushed through 40-mesh, will not yield to amalgamation more than 18 per cent. of the gold, the remainder being so encased in the quartz that even the cyanide can dissolve only 80 per cent. of it from sand-grains 0.08 mm. in diameter.

The silver is probably partly metallic and partly in the form of silver sulphides, arsenides and antimonides. The amount of these metallic sulphides, however, is so small that the naked eye is generally unable to detect them.

III. Outline of Ore-Treatment.

Mills and Cyanide-Plants.—There are two mills, each containing 100 stamps. No. 1 was built in 1899, and No. 2 was completed but a few months ago.

In No. 1 the sand and slime are treated practically in the same way as in plant No. 2, though the material arrangement and the mechanical devises are different. The greatest difference between the two plants is, that No. 1 has no tube-mills for regrinding the sand. At present the coarse sand is brought over to plant No. 2 to be reground and treated; though in the near future two tube-mills will be added for grinding exclusively the sand from Mill No. 1.

The ore is dumped from skips into ore-bins, crushed through gyratory and jaw-crushers, and thence conveyed to the mills by cars, or by belt-conveyors. The mills are of the standard Allis & Chalmers pattern. The ore is stamped through from 25- to 35-mesh screens, and runs over amalgamated plates, which catch from 13 to 18 per cent. of the gold and from 1 to 5 per cent. of the silver. The bullion from the retorted amalgam contains about equal parts by weight of silver and gold. The pulp from the plates is reground through tube-mills and then flows to the cyanide-plants, where it is separated into slime and sand, which are treated separately.

Fig. 1, showing the method of treatment at Mill No. 2, is self-explanatory, but, as the experiments given in this paper concern almost exclusively Mill No. 2, we shall give, regarding this plant, additional information which it was not possible to put on the diagram.

In Mill No. 2 the ore is crushed by 100 stamps, each weighing 1,140 lb., and dropping 6 in. 100 times per min.; the discharge is 2.5 in. through 25-mesh brass wire screen (0.74-mm. aperture). The duty per stamp is 4.7 tons per 24 hr. of actual work. The ratio of mill-water to ore is from 9 to 10.

Owing to the scarcity of water in the district, the mill-water, after separation from the slime, has to be pumped back to the large storage-tanks. About 340 tons of mill-water pass daily into the cyanide solutions, being carried in as moisture in the slime, which contains 53 per cent. of water, and in the sand, which contains 15 per cent. of water. The discharged slime carries 40 per cent., and the sand 15 per cent., of water; therefore, about 75 tons of weak solution have to be discharged daily.

The pulp from the plates is classified by two 4.5-ft. cones put in series with two 2-ft. cones, called "pulp-thickeners," giving

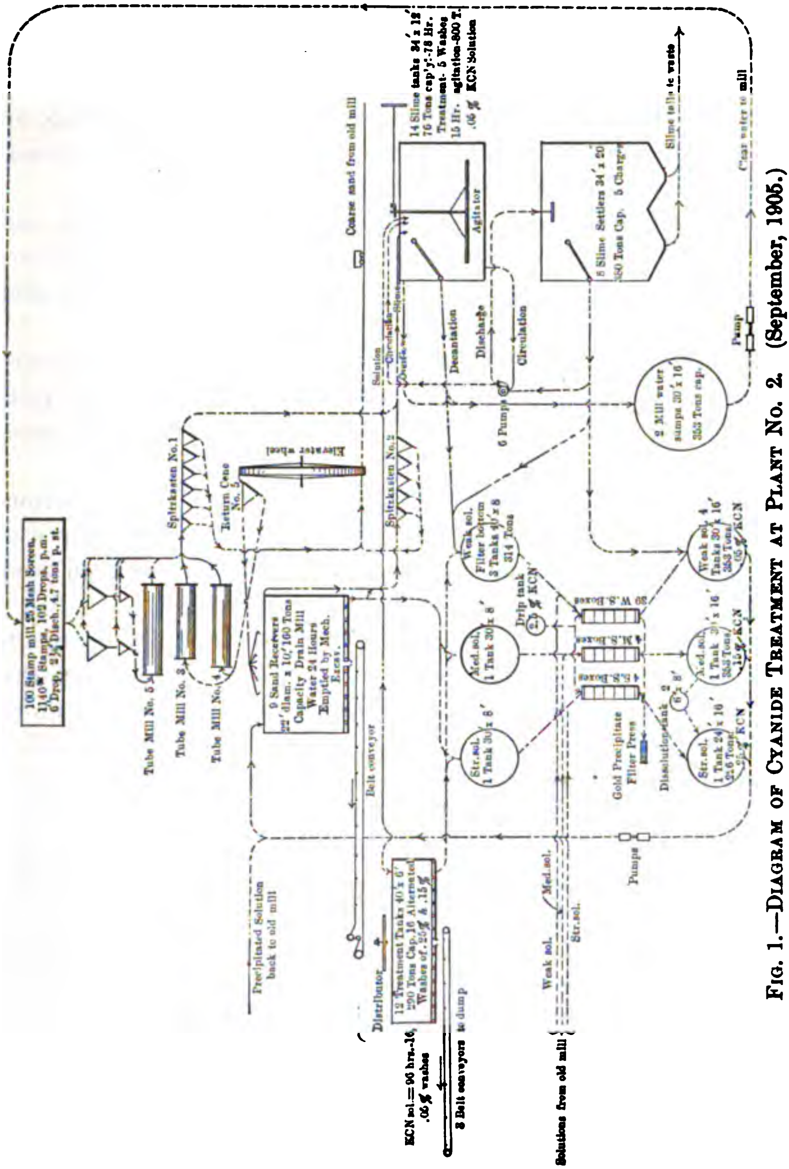

100 Stamp mill 25 Mesh Screen. 1140# Stamps, 102 Drops, p.m. 6 Drop, 2¾ Disch., 4.7 tons p. st.
Tube Mill No. 5
Tube Mill No. 3
Tube Mill No. 4
Spitzkasten No. 1
Spitzkasten No. 2
Return Cone No. 5
Elevator wheel
9 Sand Receivers 22' diam. x 10' 160 Tons Capacity Drain Mill Water 24 Hours Emptied by Mech. Excav.
Belt conveyor
Distributor
12 Treatment Tanks 40' x 6' 220 Tons Cap. 16 Alternated Washes of .25% & .15%
KCN sol.=96 hrs.-16 .05% washes
3 Belt conveyors to dump
Precipitated Solution back to old mill
Solutions from old mill
Weak sol.
Med. sol.
Str. sol.
Pumps
Coarse sand from old mill
Solution
Circulation
Slime
14 Slime tanks 34' x 12' 76 Tons cap'y.-78 Hr. Treatment- 5 Washes 15 Hr. agitation-800 T. .05% KCN Solution
Agitator
Decantation
Discharge
Circulation
6 Pumps
8 Slime Settlers 34' x 20' 350 Tons Cap. 5 Charges
Slime tails to waste
Clear water to mill
Pump
2 Mill water sumps 30' x 16' 353 Tons cap.
Weak sol. Filter bottom 3 Tanks 30' x 8 314 Tons
Drip tank 2½% KCN
Med. sol. 1 Tank 30' x 8'
Str. sol. 1 Tank 30' x 8'
20 W.S. Boxes
M.S. Boxes
4 S.S. Boxes
Gold Precipitate Filter Press
Dissolution tank 2 6' x 8'
Weak sol. 4 Tanks 30' x 16' 353 Tons .05% KCN
Med. sol. 1 Tank 30' x 16' 353 Tons .15% KCN
Str. sol. 1 Tank 24' x 16' 226 Tons .25% KCN

FIG. 1.—DIAGRAM OF CYANIDE TREATMENT AT PLANT NO. 2. (September, 1905.)

two classified products, namely,—an overflow containing about 81 per cent. of slime and representing 52 per cent. of the total mill-output, and a discharge containing 9 per cent. of slime.

The discharge of the pulp-thickeners is run through tube-mills, where from 40 to 50 per cent. of the sand is slimed, according to the various conditions under which the tube-mills are working.

The pulp discharged by the tube-mills joins the overflow from the four cones and forms a final product, containing, on an average, 69 per cent. of slime. The product is then classified and handled, as shown in Figs. 1 and 2.

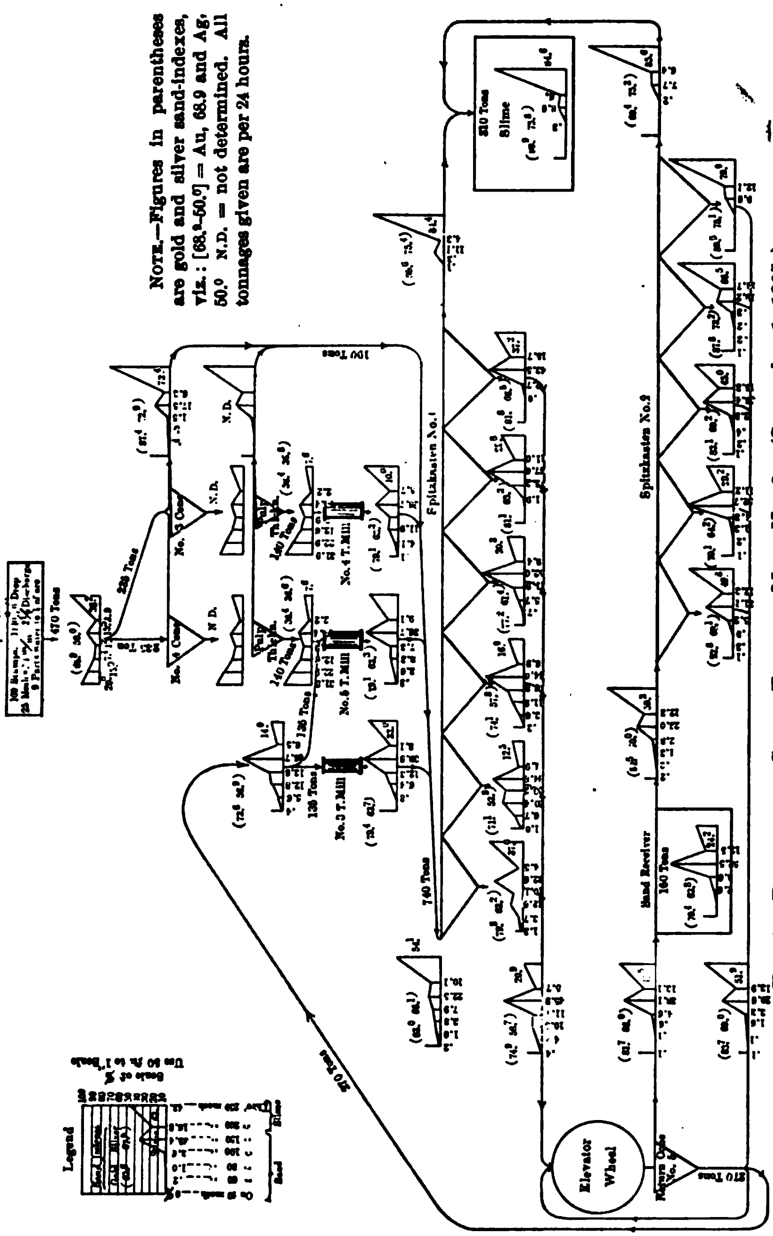
The final result is to separate two mill-products,—sand and slime; the former, containing about 20 or 25 per cent. of slime, and representing about 35 per cent. of the rock crushed, and the latter, containing about 5 or 10 per cent. of sand.

2. *Classification of Mill-Products.*—Numerous sizing-tests were made to determine the classification wrought by the cone, spitzkasten, etc., and to measure the grinding-efficiency of the tube-mills.

In order to grasp more easily the meaning of the numerous figures thus obtained, a graphic method of representation was resorted to, and, wherever possible, such method has been used to represent all the other tests and experiments.

For each sizing-test, a small diagram was drawn, the percentage of each size of sand being brought as an abscissa of the diagram, as is shown in Fig. 2. The coarser the sand, the more will the diagram swell to the left; on the other hand, a perfect slime will be represented by the dotted triangle on the right. Fig. 2 shows the handling and classification of the mill-pulp from Mill No. 2. The small sand-diagrams, inserted at the point where each separation comes to an end, exhibit the transformation produced in the sand.

The method of classification, shown in Fig. 2, is at present undergoing modification. In the near future the buckets of the sand-wheel will be divided into two compartments; one, for elevating the coarse sand which has to be reground in the tube-mills, and the other, for elevating the fine sand which goes to the sand-receivers. By such a method the capacity of the sand-wheel will be doubled. The spitzkasten will be cut out, and cones used exclusively for classifying. By this arrangement it is hoped to obtain a closer separation of coarse sand, fine sand and slime,—a condition which is essential for economically regrinding the coarse sand.



NOTE.—Figures in parentheses are gold and silver sand-indexes, viz.: [68.9-50.0] = Au, 68.9 and Ag, 50.0 N.D. = not determined. All tonnages given are per 24 hours.

FIG. 2.—DIAGRAM OF SIZING-TESTS AT MILL NO. 2. (September 1, 1905.)

IV. RELATION BETWEEN THE DIAMETER OF SAND-GRAINS AND EXTRACTION.

The relation between the diameter of the sand-grains and the maximum possible gold- and silver-extraction by the cyanide process has been taken as the starting-point in the determination of economical limit in regrinding the sand.

For this purpose all the available data were collected, and several sizing-assay tests were made, both of the untreated pulp and of the tails. These data have been plotted in Figs. 3 and 4,[1] the former giving the gold- and silver-values of the sand-grains of a given diameter before treatment; and the

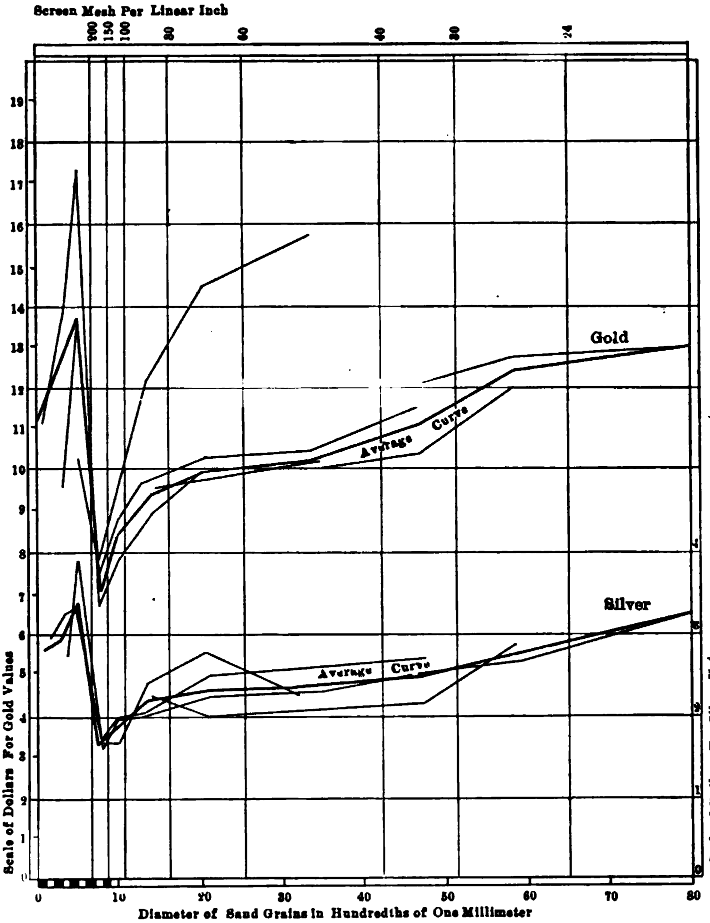


FIG. 3.—RELATION BETWEEN DIAMETER OF SAND-GRAINS AND VALUES OF HEADS.

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[1] In these diagrams are included the sizing-assay tests published by Charles Butters and E. M. Hamilton in their valuable paper, "The Cyaniding of Ore at El Oro," etc., *Transactions of the Institution of Mining and Metallurgy*, October, 1904.

latter, the values of the same grains after treatment, as well as the resulting average gold- and silver-extraction.

The plotting of these diagrams was only rendered possible by the reduction of all the assay-values to a common base, namely,—to an ideal assay-value of the original pulp of $10 of

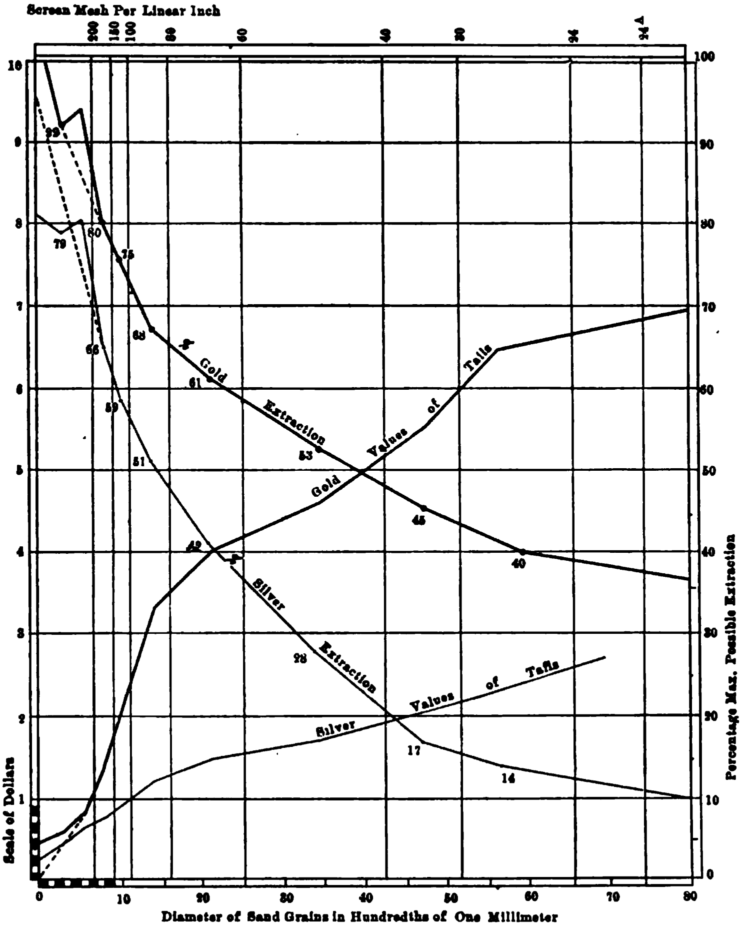


FIG. 4.—RELATION BETWEEN DIAMETER OF SAND-GRAINS, VALUES OF TAILS AND EXTRACTION.

gold and 5 oz. of silver per ton. This assumption is justified by the fact (verified by experiments) that the values of the tails are in linear proportion to the value of the heads. (A high-grade slime will give a somewhat higher extraction than a low-grade one; but the difference is small.) Therefore, all gold-values, both of the heads and the tails, were multiplied by $10 and divided by the gold-assay value of the untreated pulp; and the silver-values were multiplied by 5 oz. and divided by the silver-value of the untreated pulp.

Examining the diagrams of the values of the heads in function of the diameter of the grains, Fig. 3, it is seen that the values of the sands decrease, in a fairly constant way, as the size of the grain decreases, until a diameter of 0.15 mm. is reached. From 0.15 to 0.08 mm. the values drop rapidly, reaching a minimum at 0.08 mm.; then they rise rapidly, being, at 0.05 mm., far above the average value of the pulp, and, afterwards, begin to drop again for those grains which constitute the slime. The values of the tails, Fig. 4, decrease proportionally to the diameter of the grain, but do so much more rapidly between 0.15 and 0.08 mm. To explain this anomaly, both for the heads and for the tails, the intimate structure of the ore must first be investigated.

The El Oro ore is a very hard, compact quartz, in which the values are disseminated in a remarkably fine state of division and, locally, in a very uniform way. The quartz was evidently deposited from aqueous solutions, and probably the gold and silver were precipitated at the same time as the quartz. The structure of the quartz is micro-crystalline, and the silver-minerals and the gold were precipitated between the faces of the elementary quartz crystals.

The structure of the ore, however, is remarkably compact, and therefore practically impermeable to the solutions; hence, only those minerals can be brought into solution which are on the surface of the sand-grains, or which are so encased in the quartz that at least a part of their surface is exposed. Consequently, the maximum extraction must be proportional to the surface of the ore exposed by crushing; or, in other words, must be proportional to the inverse of the diameter of the grains. It follows that the curves representing the average gold- and silver-extraction, in relation to the diameter of the grains, ought to have the form of a parabola, and this is about what has been found by experiment, as can be verified by Fig. 4.

What we have just said about the structure of the ore suggests another consideration, namely, the breaking-off of the metallic mineral from the surface of the sand-grains. This breaking-off will produce an impoverishment of the sand-grains, which will be so much more sensible as the diameter of the grains becomes smaller. That class of sand, the grain-diameter of which is equal to the diameter of the elementary quartz crystals constituting the ore, will present a material in which the greatest part of the metallic minerals will be subject to breaking-off from the quartz crystals; or, at least, will be most completely exposed to the dissolving-action of the cyanide.

This is what probably happens when the ore is crushed to 0.08 mm. grains, since 0.08 mm. is probably the average diameter of the elementary quartz crystals.

On the other hand, the metallic minerals are so small that almost never can they be detected by the naked eye, and, therefore, will pass easily through a 200-mesh screen; but, owing to their high specific gravity, they will hydraulicly separate with the very fine sand passing 200-mesh.

These considerations explain satisfactorily the anomalies noted in all the curves plotted on Figs. 3 and 4. Perhaps other explanations will be found, but one fact remains beyond dispute, namely, that both the gold- and silver-extraction are greatly increased by crushing finer than 0.10 mm., and, as the crushing to such fineness is economically possible by means of tube-mills, it may be safely said that the economical point in regrinding is beyond the size of 0.10-mm. grains.

V. SAND-INDEX.

From the foregoing, the maximum possible extraction is seen to be constant for each size of sand-grains, independently of the original assay-value of the pulp.

It is, therefore, easy to understand that we can safely calculate, *a priori*, the probable gold- and silver-extraction for a class of sand when its mechanical composition is known by sizing-tests.

To do this, we simply have to multiply the percentage of sand retained on each sieve by the average percentage-extraction for that class of sand, and then to take the sum of all the products thus obtained. The probable percentage of extraction thus calculated is what we shall call throughout this paper the "index" of a given class of sand, since it represents a number proportional to the fineness of the sand considered from the economical point of view. To be perfectly exact we ought not to use as coefficient the percentage-extraction shown by the extraction-curves in Fig. 4; since the values of the heads are not constant for the different sizes of grain. Each coefficient ought to be modified proportionately to the ratio between the assay-values of the sand-grains to which it refers, and the assay-value of the total pulp; but in practice the sand-indexes check so closely with the extraction actually obtained, that there is no need to complicate the calculations in this way.

As an example, we give the calculation of the sand-indexes for the 281-ton lot of sand treated in test "T," Fig. 8.

TABLE I.—*Sand-Indexes of* 281-*Tons Treated by Test "T."*

1	Screens used ; mesh..................	On 40.	On 60.	On 80.	On 100.	On 150.	On 200.	Thro' 200.	Total.
2	Per cent. sand retained.......	0	0.2	1.0	3.6	35.4	16.8	43.0	100
3	Av. diameter of grains, mm.	0.47	0.33	0.26	0.14	0.10	0.09	0.04	....
4	Per cent. probable gold extraction..........................	45	53	61	68	75	80	92	....
5	Per cent. probable silver extraction..........................	17	28	42	51	59	66	79	....
6	Product of per cent. sand by per cent. gold extraction..	0	0.10	0.61	2.44	26.60	13.44	39.60	82.8
7	Product of per cent. sand by per cent. silver extraction.	0	0.05	0.42	1.84	20.90	11.10	34.00	68.3

The calculated extractions, or sand-indexes, are:—gold, 82.9; silver, 68.3; while the actual extractions in test "T" were:—gold, 82.9; silver, 69.5.

The sand-indexes have a great importance in the determination of the economical efficiency of the tube-mills.

Every time a sand passes through a tube-mill its composition becomes finer; the ground product will yield a larger proportion of its values to the cyanide treatment, or, in other words, a certain percentage of the gold and of the silver will have been freed by the action of grinding. This percentage represents the gross profits obtained by the work done. The economical point of regrinding will be reached when the difference between the total values freed and the total cost of regrinding will be but a few cents. This, however, does not mean that it would pay to slime all the sand, since the cost of grinding increases rapidly with the increased fineness of the sand to be reground.

Fine grinding will increase the total ratio of slime to sand, and, therefore, would apparently tend to diminish the cost of treatment for the slime and increase that for the sand.

This result, however, does not correspond to the practice, as the tonnage of sand to be treated on the 200-ton sand-treatment plant will be kept constant by sending the coarse sand of the old mill to the new plant to be reground and treated. Besides this, there are about 500,000 tons of old tailings, containing about $4.60 in gold and 2 oz. of silver per ton, which some day will have to be reground and treated.

VI. Tube-Mills.

At present there are three tube-mills in use at the new plant, and two additional ones will soon be added for grinding the sand of the old mill. The mills were constructed by the Fried. Krupp Aktiengesellschaft Grusonwerk, of Magdeburg, Germany, and the principal data concerning them are as follows:—

Mill	No. 3.	No. 4.	No. 5.
Internal diameter of drum	47 in.	59 in.	59 in.
Internal length of drum	19 ft. 6 in.	23 ft.	26 ft.
Revolutionsper minute	32	27.5	28.5
Pounds of pebbles in mill when half full	11,700	21,800	24,700
Capacity per 24 hr., tons	100–120	130–150	150–180
Cost of mill	$2,940.	$3,850.	$4,750.

Bulk of pebbles = 100 lb. per cu. ft.

The tube-mills are set on concrete foundations and held in place by anchor-bolts. Experience thus far at El Oro indicates that the foundations cannot be made too solid. The mills, when in motion and heavily loaded with pebbles, bear very heavily on the foundations, which, owing to the mechanical arrangement of the mills, cannot be made on the top as wide as is desirable. The cast-iron bed-plates have a tendency to dig into the cement, and it is advisable to enlarge the bearing-surface of the bed-plates by placing larger cast-iron plates under them. A piece of rubber belt placed below these plates will be found to be advantageous. The vibrations produced by the spur-gears are violent, and the anchor-bolts easily crystallize and break; therefore, pockets are advisable. The driving-pinion ought to revolve in such direction as to lift the gearing of the tube-mill, and press down on its own bearing. On the contrary, it is continuously pulling on the anchor-bolts of the boxes, thus tending to loosen the nuts and to break the bolts.

Notwithstanding this objection, we can safely declare that, in our opinion, the tube-mills are the best machines tried at El Oro for the fine grinding of very hard quartz sand.

Of the three tube-mills in use, No. 3, the smallest, has given most satisfaction and least trouble. Its capacity is not much below that of the other two; but the cost of running it is much smaller. The main advantage is that the mill is comparatively light and compact, and, therefore, seldom gets out of order. The shut-down of one mill represents a great loss in money; hence, reliability is more important than capacity.

The liners are kept in place by counter-sunk bolts passing through the shell. When a liner gets worn out the bolts begin to leak, and thus give notice that that special liner needs to be replaced. Such leakage, which is a useful indication regarding the liners, ought, however, to be avoided for the bolts holding the head-plates; because the sand leaking from behind the bolts will move by centrifugal force towards the driving-gear, and cause a rapid wearing of the cogs.

The three tube-mills are placed parallel to each other, and are driven by belts from the line-shaft of the stamp-mill. It would be of great advantage to have positive clutches on the pulleys of the line-shaft, as any repairs necessary to the belts or to the driving-pulleys of the tube-mills require the shut-down of the whole stamp-mill.

The pulp from the stamps is, as previously mentioned, classified in coarse sand, and an overflow containing 81 per cent. of slime and some fine sand. The coarse sand can be sent to the head of any of the three mills, or divided among them. The insufficiently-ground sand leaving the mills is elevated, separated from the fine sand and slime, and can be likewise returned to any of the three mills, or divided among them. Figs. 5 and 6 give two diagrams of the combination generally used in grinding and regrinding the sand.

1. *Grinding Efficiency.*—The tube-mills have been working on sand of different coarseness. In May the stamps were crushing through 40-mesh, in June through 30-mesh, and latterly through 25-mesh screen.

About 150 sizing-tests were made of the heads and tails. It is very hard to discuss the results of such work, especially because the variable factors in the operation of grinding vary independently from each other. In an experimental plant it would be possible to keep varying one of these factors alone (as quantity of pebbles, rate of feed, ratio of water to sand, etc.), and note the relation of all the other factors to the variable one; but in experimenting on a working-plant this is not possible.

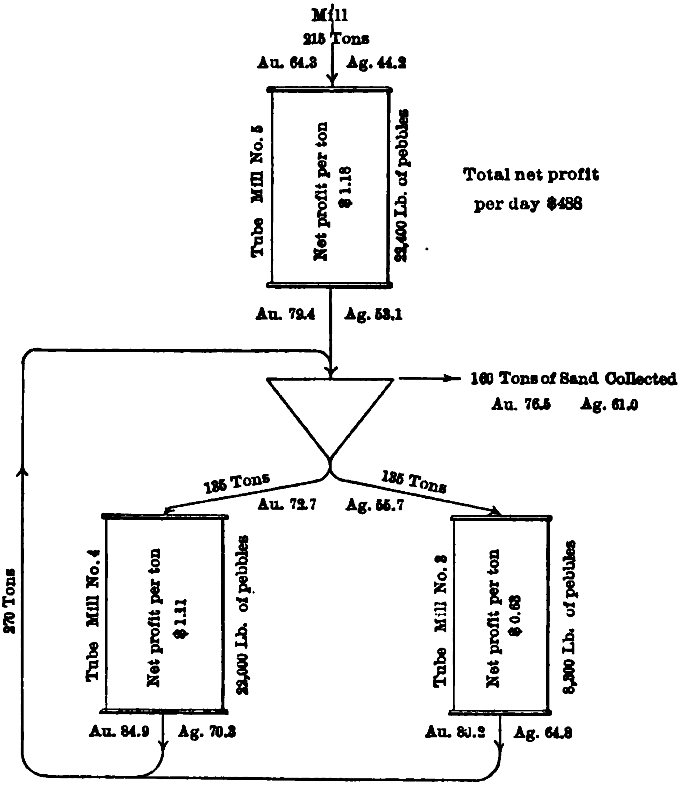


FIG. 5.—DIAGRAM SHOWING THE METHOD OF GRINDING AND REGRINDING SAND IN TEST "O." (August 13, 1905.)

For the same reason it was not possible to represent graphically all the results obtained; hence we have been obliged to tabulate them.

The understanding of the tables is greatly facilitated by the use of the sand-indexes, by means of which we can represent with one figure (dollars and cents) the work wrought by a tube-mill under given conditions. Without the sand-indexes we would have to study the relation of 14 numbers among themselves.

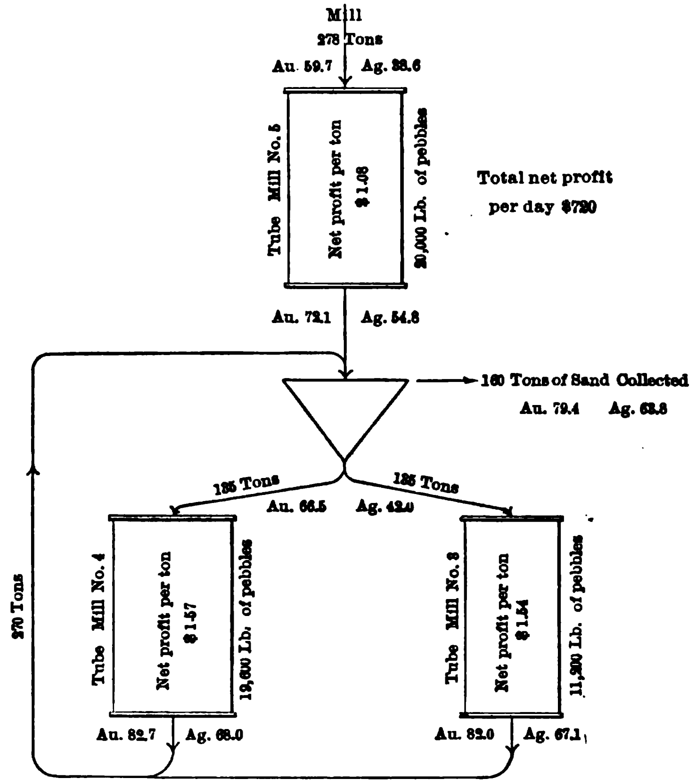


FIG. 6.—DIAGRAM SHOWING THE METHOD OF GRINDING AND REGRINDING SAND IN TEST "R." (August 17, 1905.)

Economically, the only interest in sand is to know the value, in dollars and cents, that can be extracted from it. Some grinding-machinery may produce much slime, and some comparatively coarse sand; other machines may be poor slimers, but produce a large percentage of very fine sand. By means of the sand-indexes we realize immediately which of the two products is the finer, considered from an economical point of view, while at times it would be impossible to do so by simply looking at the figures given by the sizing-tests.

Tables II. to V. give the results of a number of tests made on the three tube-mills. The factors which vary and influence the efficiency of the tube-mills are,—the coarseness of the heads, the rate of flow, and the amount of pebbles in the mill. The other factors, namely, the character of the ore, the ratio of sand to water, size of pebbles, etc., may be considered to have remained constant throughout the tests.

The moisture of the pulp fed to the mills averaged from 50 to 75 per cent.

In Tables II. to V. the coarseness of the sand is represented by the gold- and silver-indexes; the useful work done by the tube-mills is represented by the increased extraction produced, by the gross profit per ton ground, or by the net profit obtained per ton, or per 24 hr., of continuous run.

In Table V. are given the sizing-tests of a number of sands of different sand-indexes. The reader, wishing to know the composition of a sand having, say, a gold sand-index of 84.9 per cent., can refer to this table, and get a fairly exact idea of what would be a sizing-test on such class of sand.

Naturally, there is an endless number of sands of a given sand-index, but of different composition; though, with the present system of classifiers in use, such differences are always small.

The reader can also refer to Fig. 2, from which are taken several of the sizing-tests given in the Tables II. to V.

It is difficult to discuss completely the results tabulated in Tables II. to V., owing to the reasons already mentioned. However, we can safely assert, that:—

(1) *The efficiency increases proportionally to the amount of pebbles contained in the mill*, as may be seen:—

In Table II. by comparing Test No. 2 with Test No. 6.
In Table II. by comparing Test No. 5 with Test Nos. 9 and 12.
In Table III. by comparing Test No. 2 with Test No. 8.
In Table III. by comparing Test No. 6 with Test No. 9.
In Table IV. by comparing Test No. 1 with Test No. 4.
In Table IV. by comparing Test No. 2 with Test Nos. 5 and 6.

TABLE II.—*Showing the Efficiency of Tube-Mill No. 3.*

No.	Tons per 24 Hr.	Pounds of Pebbles in Tube-Mill.	Heads.			Tails.			Increased Extraction.		Gross Profit per Ton.		Net Profit.	
			Au.	Ag.	Per Cent. Slime.	Au.	Ag.	Per Cent. Slime.	Au.	Ag.	Au.	Ag.	Per Ton.	Per 24 Hr.
			Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	$	$	$	$
1	130	....	63.8	44.0	5.7	81.7	66.2	44.5	17.9	22.2	1.43	0.38	1.47	191
2	130	12,000?	64.8	45.7	7.3	82.4	67.3	47.0	17.6	21.6	1.41	0.37	1.44	187
3	135	11,200	66.5	42.0	8.8	82.0	67.1	50.6	15.5	25.1	1.24	0.48	1.33	180
4	100?	....	63.4	42.9	7.1	83.4	66.7	46.0	20.0	24.6	1.60	0.42	1.68	168
5	84	12,000?	64.1	44.0	7.5	86.0	71.3	62.0	21.9	27.3	1.75	0.46	1.87	157
6	130	8,000?	66.4	47.4	7.9	79.8	63.6	34.9	12.9	16.2	1.03	0.27	0.96	125
7	69	12,400?	65.0	45.2	8.2	85.9	71.1	61.8	20.9	25.9	1.67	0.44	1.77	123
8	100?	7,500?	63.6	46.2	10.3	79.4	63.7	33.4	15.8	17.5	1.26	0.30	1.22	122
9	93	10,000	66.4	47.8	7.8	82.1	66.9	44.5	15.7	19.6	1.26	0.33	1.25	116
10	250	11,000	67.1	47.5	11.0	78.5	56.5	22.0	6.4	9.0	0.51	0.15	0.32	80
11	75	....	66.9	48.1	7.9	81.3	65.9	42.4	14.4	17.8	1.15	0.30	1.11	83
12	75	9,000?	67.5	50.0	8.7	79.5	64.0	40.0	12.0	14.0	0.96	0.24	0.86	64
13	140	8,300	72.7	55.7	13.3	80.2	64.8	39.0	7.5	9.1	0.60	0.15	0.41	67
14	135	11,000	71.5	54.5	12.3	79.0	64.0	38.0	7.5	9.5	0.60	0.16	0.42	57
15	135	9,500	73.6	56.9	14.0	79.4	63.4	33.0	5.8	6.8	0.46	0.11	0.23	31
16	135	10,900	73.3	56.5	15.6	78.5	63.0	32.2	5.2	6.5	0.42	0.11	0.19	26
17	170	11,000	76.7	61.6	20.3	80.0	64.7	37.0	3.3	3.1	0.26	0.05	0.03	–5

TABLE III.—*Showing the Efficiency of Tube-Mill No. 4.*

No.	Tons per 24 Hr.	Pounds of Pebbles in Tube-Mill.	Heads.			Tails.			Increased Extraction.		Gross Profit per Ton.		Net Profit.	
			Au.	Ag.	Per Cent. Slime.	Au.	Ag.	Per Cent. Slime.	Au.	Ag.	Au.	Ag.	Per Ton.	Per 24 Hr.
			Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	$	$	$	$
1	200	....	64.6	44.4	8.4	83.4	68.6	51.0	18.8	24.2	1.44	0.41	1.48	296
2	150	22,000?	64.2	44.1	8.9	83.8	69.0	50.0	19.6	24.9	1.57	0.42	1.62	243
3	135	18,600	58.4	36.6	7.6	79.1	63.3	40.0	20.7	26.7	1.65	0.45	1.73	234
4	270	19,500	65.2	45.0	10.0	75.5	61.4	30.2	10.3	16.4	0.82	0.28	0.73	197
5	97	....	63.4	48.1	4.8	86.1	71.2	64.3	22.7	28.1	1.82	0.48	1.93	187
6	117	18,000?	66.2	46.9	9.8	85.5	71.1	60.8	19.3	24.2	1.54	0.41	1.58	185
7	135	19,600	66.6	42.0	8.8	82.7	68.0	50.0	16.1	26.0	1.29	0.44	1.36	184
8	139	19,400	64.7	43.7	16.3	81.0	66.0	44.4	16.3	22.3	1.30	0,38	1.31	182
9	111	16,000	63.0	42.7	4.9	80.1	64.6	38.0	17.1	21.9	1.37	0.37	1.37	152
10	135	22,000	72.7	55.7	18.3	84.5	70.3	56.5	11.8	14.6	0.94	0.25	0.82	111
11	200	....	70-5	53.3	9.1	76.8	60.8	21.5	6.3	7.5	0.50	0.13	0.26	52

TABLE IV.—*Showing the Efficiency of Tube-Mill No. 5.*

No.	Tons per 24 Hr.	Pounds of Pebbles in Tube-Mill.	Heads.			Tails.			Increased Extraction.		Gross Profit per Ton.		Net Profit.	
			Au.	Ag.	Per Cent. Slime.	Au.	Ag.	Per Cent. Slime.	Au.	Ag.	Au.	Ag.	Per Ton.	Per 24 Hr.
			Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	$	$	$	$
1	215	26,800	66.3	45.6	18.5	84.0	69.0	53.5	17.7	23.4	1.41	0.40	1.41	303
2	274	22,500	66.0	46.7	7.6	79.1	63.3	35.1	13.1	16.4	1.05	0.28	0.93	255
3	139	19,900	58.9	35.4	7.6	79.4	64.4	41.2	20.5	29.0	1.64	0.49	1.73	241
4	215	22,400	64.3	44.2	9.0	79.4	63.1	36.8	15.1	18.9	1.21	0.31	1.12	241
5	278	20,000	59.7	38.6	9.6	72.1	54.8	22.8	12.4	16.2	0.99	0.27	0.86	239
6	274	19,500	66.9	49.5	16.3	76.2	60.9	31.6	9.3	11.4	0.74	0.19	0.53	145
7*	72	22,000?	62.9	42.5	8.0	87.1	72.6	70.0	24.2	30.1	1.94	0.51	1.91	138
8*	52	22,000?	68.3	45.0	10.0	85.4	71.0	61.0	17.1	26.0	1.37	0.44	1.00	52
9*	24	22,000?	65.7	47.2	12.0	89.5	75.7	83.4	23.8	28.5	1.90	0.48	1.31	31

* Test by E. M. Hamilton, *op. cit.*, pages 13, 16, 22.

TABLE V.—*Sizing-Tests of Sands of Different Sand-Indexes.*

Sand-Indices.		Sample from Where Taken.	On						Through
Au.	Ag.		40	60	80	100	150	200	200
58.4	36.6	Discharge pulp thickness	81.9	22.9	12.6	7.9	14.4	2.2	7.6
63.4	43.1	Head Tube-Mill No. 4	7.5	28.0	24.5	12.0	20.3	2.9	4.8
65.5	48.4	Head Tube-Mill No. 4	1.8	14.2	21.0	15.2	27.0	5.7	10.0
67.5	50.0	Head Tube-Mill No. 3	1.9	14.9	26.0	15.4	27.4	4.8	8.7
69.2	51.6	Head Tube-Mill No. 4	1.4	12.8	22.7	16.3	26.7	5.4	18.6
71.5	54.5	Head Tube-Mill No. 4	1.1	8.6	14.3	16.0	42.1	5.0	12.8
72.8	56.1	Head Tube-Mill No. 4	......	0.7	9.8	14.5	51.0	9.3	14.8
74.1	57.8	3d plug of spitz No. 1	0.2	3.6	11.9	16.8	44.0	6.4	16.6
76.5	61.0	Sand collected	......	0.1	2.9	8.6	52.5	12.5	24.2
78.5	63.0	Tails Tube-Mill No. 3	0.1	1.1	7.8	10,1	39.2	9.5	32.2
80.1	64.6	Tails Tube-Mill No. 4	0.1	1.7	7.8	11.0	30.8	11.4	38.0
81.8	65.9	Tails Tube-Mill No. 3	......	1.3	5.9	7.1	31.5	11.8	42.4
82.4	67.3	Tails Tube-Mill No. 3	......	1.2	2.8	5.4	34.2	9.3	47.0
83.4	68.6	Tails Tube-Mill No. 4	......	0.2	2.3	4.5	27.8	13.8	51.0
84.4	69.7	Tails Tube-Mill No. 4	......	0.2	1.8	4.1	26.1	12.4	55.4
84.9	70.3	Tails Tube-Mill No. 4	......	0.1	0.8	3.8	25.7	13.2	56.5
87.8	73.2	4th plug spitz No. 2	......	......	0.5	0.3	19.2	14.7	66.5
89.9	75.8	Slime collected	......	......	......	0.3	8.6	6.9	84.6
91.3	78.0	Slime collected	......	......	......	......	......	5.0	95.0

(2) *The efficiency increases with the coarseness of the sand fed to the mill*, as may be seen:—

On Table II. by comparing Test No. 3 with Test No. 14.
On Table II. by comparing Test No. 13 with Test No. 17.
On Table III. by comparing Test No. 3 with Test No. 7.
On Table III. by comparing Test No. 1 with Test No. 11?
On Table III. by comparing Test No. 2 with Test No. 10.
On Table IV. by comparing Test No. 5 with Test No. 6.

(3) *The efficiency decreases proportionally to the rate of feed*, as may be seen:—

On Table II. by comparing Test No. 2 with Test No. 5.
On Table II. by comparing Test No. 3 with Test No. 10.
On Table III. by comparing Test No. 5 with Test No. 1.
On Table III. by comparing Test No. 1 with Test No. 2.
On Table IV. by comparing Test No. 2 with Test No. 9.
On Table IV. by comparing Test No. 3 with Test No. 5.

Regarding the net profit per day given by a mill, it varies with the variation of the three factors just mentioned. It is difficult to say under which conditions the mills are doing the most satisfactory work, since it greatly depends upon the main object of a plant, whether it is to produce a large amount of money or to obtain a high efficiency.

Taking the high efficiency as the main object, it is important not to try to get a very fine product at the first operation by reducing the feed below 3 tons an hour. It is far better somewhat to overcrowd the mills, to separate the slime and fine sand, and to return the insufficiently-ground sand to the mills. The returning sand can be classified, by means of cones, to any desired degree of fineness or coarseness.

Let us now suppose the coarse sand from the stamps to be ground or reground by two tube-mills placed in series, yielding a final product which, classified, will give 69 per cent. of slime and 31 per cent. of sand; 89 per cent. of the sand will pass 100-mesh, and 53 per cent. will remain on 150-mesh (Table II., Test No. 17). If we run this sand through a tube-mill the increased extraction will hardly pay for the cost of regrinding.

Supposing, now, we take the same coarse sand from the stamps and feed it very slowly to a tube-mill so as to obtain a very fine product, we shall have the mill doing two distinct things, namely, first, breaking up the coarse sand-grains to 150-mesh grains, and second, grinding such small grains to finer ones.

Now, we know that the second operation does not give a profit; and, therefore, it is more profitable to overcrowd the mill and get the fine sand through as quick as possible, then to separate the fine sand and slime and to return to the mill only that sand which it is profitable to grind.

This does not mean, however, that the El Oro ore cannot be ground economically finer than through 100-mesh screen.

With the present system of classification by spitzkasten and cones, the fine return sand cannot be fed to the mills with less than about 70 per cent. of moisture, and fine sand needs to be ground in the state of a thick pulp, while the coarse sand can be ground in a state of greater dilution.

We have seen, previously, that the value of the tails drops rapidly for sands which will pass a 150-mesh sieve, and, therefore, it is most important (and probably will prove to be economic) to grind beyond that limit.

2. *Pebble-Consumption.*—The pebbles used at El Oro are the so-called "Danish" pebbles, and cost $36.80 per ton brought to the mill.

Tube-mill No. 3 shows an average consumption of 3.7 lb. of pebbles per ton of sand passing through. Tube-mill No. 5 shows a consumption of 3.9 lb., and No. 4 of 9.2 lb. The average consumption for the last 4 months has been 5 lb. per ton.

The reason No. 4 consumes more than twice as much as the other two mills is, that the fine sand, returning to be reground, was chiefly fed to this mill.

3. *Liners.*—The former liners came from Germany, but at present all the liners are made in the foundry of the El Oro Mining & Railway Co., Ltd. These last as long as the imported ones, and cost about one-half as much.

The consumption of liners is about 1.2 lb. per ton of sand ground, but accurate figures are not available at present.

Table VI. shows the wear of one set of Krupp liners. It is interesting to note how much greater is the rate of wearing near the feed-end of the mill, indicating that the greater part of the work is done in the first half of the mill.

TABLE VI.—*Consumption of Liners in Tube-Mill No. 3.*

Date. 1905.	Number of Liners Changed in the				Head-Plates.	Sundry.
	1st Row.	2d Row.	3d Row.	4th Row.		
May 3	Mill	started	with	new set	of	liners.
June 29	1	......	......	......	......	......
July 3	2	......	......	......	......	......
July 6	2	......	......	......	......	......
July 12	5	2	......	......	......	1 manhole.
July 13	......	2	......	......	......	......
July 14	......	5	......	......	1	1 screw.
July 19	......	......	......	4	......	......
July 25	3	4	4	......	......	......
July 30	......	......	1	......	4	1 screw.
August 15	......	......	3	......	......	......
August 16	......	......	2	6	1	......
Total	13	13	10	10	6	......

NOTE.—On August 16th, head- and tail-plates were practically worn out.

Two tube-mills have been ordered for grinding the sand of Mill No. 1; these will be provided with silex liners.

4. *Cost of Grinding.*—The cost of grinding by tube-mills has been calculated per ton of sand actually passing through the tube-mills during the last 4 months' run. The cost of grinding recorded in Tables IX. and X. are given per ton of sand and per ton of slime treated, and, therefore, differ considerably from those in Tables VII. and VIII.

During the month of August, 5,170 tons of sand were run through the tube-mill, out of the 10,773 tons crushed by the stamps, and 72 per cent. of these 5,170 tons were returned to the tube-mills to be reground. The total amount of sand ground was 8,890 tons.

The costs given in Table VII. represent the average costs of grinding and regrinding. It was not possible to determine separately the exact cost of grinding the coarse sand from the batteries and the fine sand from the return cone, owing to the frequent necessity in the plant of switching one flow or the other from one mill to another. We may observe, however, that the cost of grinding fine sand is far greater than the cost of grinding coarse sand, owing to the reduced efficiency of the mills, and the greater wear of pebbles and liners, in the former case.

TABLE VII.—*Cost of Grinding and Regrinding by Tube-Mills Per Ton of Sand Actually Passing through the Mills.*

Items.	Tube-Mill No. 5.	Tube-Mill No. 4.	Tube-Mill No. 3.
Depreciation of capital (3 years)	$0.036	$0.037	$0.037
Pebble consumption @ 5 lb. per ton ground	0.092	0.092	0.092
Liners consumption @ 1.2 lb. per ton ground	0.041	0.041	0.041
Power (steam) @ $168 per year	0.180	0.148	0.118
Power (electric) @ $62.50 per year	(0.067)	(0.055)	(0.044)
Repairs	0.024	0.024	0.024
Belting (2 years)	0.003	0.003	0.003
Labor @ $3.50 per day	0.007	0.007	0.007
Supplies	0.015	0.015	0.015
Total cost per ton ground (steam)	$0.398	$0.367	$0.337
Total cost per ton ground (elect. pow.)	$0.285	$0.274	$0.263

NOTE: Belts; 140 ft. of 24-in. belt per mill.
Labor: per day, 2 peones; 1 mechanic; ¼ mech. supt.; supt. and shift-bosses, proportional part.
Liners @ $0.034 per pound.
Pebbles @ $0.0184 per pound.

VII. SLIME-TREATMENT.

The slime-pulp, overflowing from the hydraulic classifiers, is composed of about 1 part of slime to 12 parts of mill-water. The pulp flows directly to the steel treatment-tanks, 12 ft. in height and 34 ft. in diameter, entering at the center through a wooden box, so arranged as to break the force of the flow. Caustic lime is added to the mill-pulp, just before it enters the tube-mills, in the proportion of 12 lb. of lime per ton of ore. The slime settles completely, and the clear mill-water overflows and is pumped back to the mill storage-tanks.

Each slime-charge consists of from 62 to 85 tons (average 76 tons) of dry slime; and it takes about 12 hr. to collect the charge when 100 stamps are crushing through 30-mesh, and when one tube-mill alone is used for regrinding the sand; while it takes about 9 hr. when 40-mesh battery-screens are used, and when two tube-mills grind and regrind the coarse sand; and it takes only 5.5 hr. when crushing through 25-mesh, and keeping three tube-mills at work.

When a charge is completed, the slime is allowed to settle for 8 hr., at the end of which a 76-ton charge will have caked down to a depth of 50 inches. The pulp has an average specific gravity of 1.39, and will contain about 53 per cent. of water.

The clear mill-water is decanted as the settling takes place, thus avoiding any delay when the settling is considered to be complete. Lately, a larger percentage of very fine sand has been sent over with the slime, causing a far greater rate of settling of the slime.

The pulp is then set in agitation by a mechanical agitator, consisting of a horizontal wooden cross revolving in the center of the tank, 14 in. from the bottom, and at a speed of 7 rev. per minute. Two arms of this cross are 15 ft. long, and two are 7 ft. long. When the whole pulp is once set in rotation it takes about 6 h.p. to keep up the movement.

Ten minutes after the agitation has begun, a valve at the bottom edge of the tank is opened, and the pulp put into circulation by a Gwynne centrifugal pump, which elevates the pulp and throws it back to the center of the tank. Compressed air is fed near to the inlet of the pump to aërate the pulp. These centrifugal pumps do excellent work; but the cost of operating them is high, as they consume 14 h.p. The pump has to run 14.25 hr. for the complete treatment of each charge of slime. Reckoning the h.p-year at $150, the total cost of the pump-agitation is $0.14 per ton of slime.

When the pulp has been thoroughly mixed, it is sampled and the specific gravity is determined, so as to calculate the weight of each charge. Cyanide solution is then added to the pulp, and the treatment of the slime carried on.

The treatment followed at El Oro until July, 1905, graphically shown in Fig. 8, consists of 4 washes; but it was somewhat modified after the results of the tests to be described later.

1. *Preliminary Test No.* 1.—The first test made was to follow closely one slime-charge throughout its treatment, taking slime- and solution-samples every few hours, and keeping track of all the data which could have a bearing on the process of extraction. The results thus obtained were plotted in Fig. 7.

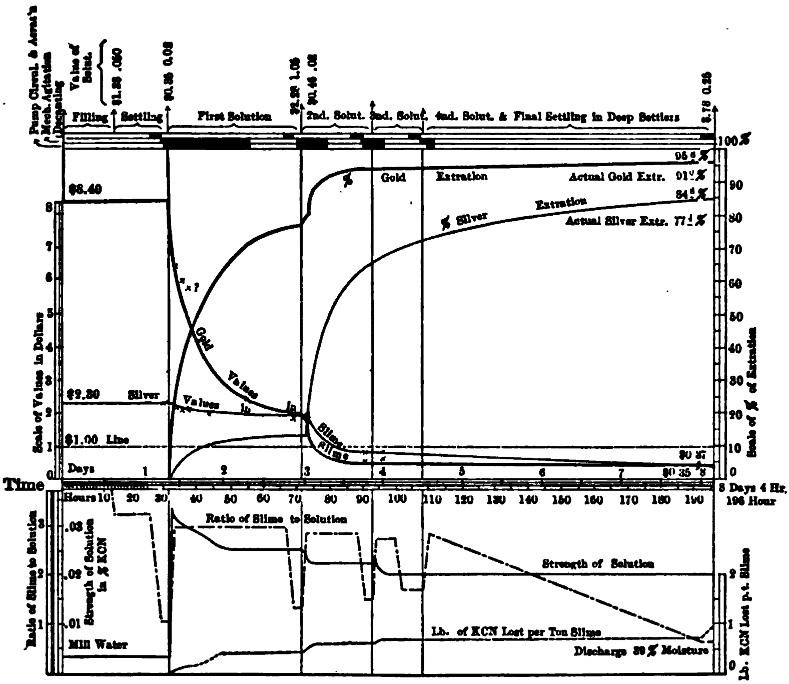
A few words on the methods follows in the graphic representation of an extraction-test will be found useful. For each test are given seven curves, representing the variations of the following data in functions of the time.

1. Undissolved gold-values contained in the slime.
2. Undissolved silver-values contained in the slime.
3. Percentage of absolute gold-extraction.
4. Percentage of absolute silver-extraction.
5. Ratio of weight of slime to weight of solution.
6. Strength of solution in per cent. of KCN.
7. Pounds of KCN consumed per ton of slime, since the beginning of the treatment.

The first 4 curves are grouped in one diagram, the 3 latter in a second one, placed below the first. Both diagrams have, as common ordinates, the time elapsed since the first moment the charge began to settle and collect in the treatment-tank. The time (= ordinates) is given in two units, days and consecutive hours; in the scale of the original blue prints, it was 15 hr. to the inch. The units of the abscissæ vary, following the curve they refer to, and their scales are given on the sides of the diagrams. On the upper part of the diagram, heavy bars mark the periods of time during which the pulp was kept in agitation by means of the mechanical agitator, or by means of the Butters' pump.

In Fig. 7 we can closely follow the process of extraction as it was practiced in the new plant up to July, 1905.

During the first 15 hr. the charge is collecting and settling; the settling continues until the 29th hour when, the mill-water having been decanted, the mechanical agitation is started, and soon followed by the pump-agitation. Up to the 31st hour the gold- and silver-values in the slime are considered to have remained constant. At the 31st hour 183 tons of 0.034-per cent.



Assay-returns marked by x.

Summary.

Quantity of slime treated,		94.4 tons.
Original assay-value,		Au. $8.40 Ag. $2.30
Absolute gold-extraction,		95.6 per cent.
Absolute silver-extraction,		84.8 per cent.
Actual gold-extraction,		91.0 per cent.
Actual silver-extraction,		77.4 per cent.
Absolute total extraction,		93.3 per cent.
Actual total extraction,		88.0 per cent.
Assay-values of tails,	Au. dissolved,	$0.39
	Au. undissolved,	$0.37
	Ag. dissolved,	$0.17
	Ag. undissolved,	$0.35
KCN consumption, per ton of slime,		96 lb.
Chemicals: lead acetate per ton of slime,		0.443 lb.
Quantity of solution used,		586 tons.
Quantity of solution precipitated,		403 tons.
Total time of treatment in slime-tanks,		80 hours.

Notes

Gold at $20.67. Silver at $0.50.

FIG. 7.—EXTRACTION TEST NO. 11, ON SLIME AT MILL NO. 2. (June 6 to 14, 1905.)

KCN solution were added, and the double agitation kept up until the 56th hour. As soon as the cyanide comes in contact with the slime, the gold begins to pass rapidly into solution, while the silver appears to be but slightly affected. The rate of dissolution of the gold, while great at the beginning, soon slacks off, and, if the first wash should be carried on indefinitely, the curve of undissolved gold-values would tend to become a horizontal line somewhere after the 100th hour. The silver-values, on the contrary, decrease in an almost linear way, as is also verified in the later experiments. It may be noticed that the gold- and silver-extraction proceeds continuously, even during the periods of settling.

From the 66th to the 69th hour, the first solution is decanted, and at the 71st hour a second addition of 0.034-per cent. KCN solution is added and mixed to the slime-pulp. During the first two hours the gold is shown to be again rapidly dissolving, while the silver is practically unaffected. At the 73d hour lead acetate was added to the charge in the proportion of 0.44 lb. of lead acetate per ton of dry slime. The lead acetate was added in form of crystals, and hung in a sack of cocoa matting at the center of the tank, where it was struck by the flow of the pulp discharged by the circulating pump. Its effect on the gold- and silver-extraction is quite remarkable. The gold-values rapidly fall to 60c., coming near to their lowest possible limit, which is a function of the average diameter of the grain, and which limit for a 95-per-cent.-through-200-mesh slime is about 55c. on an original assay-value of $9 for the pulp.

The silver-values have also a rapid but somewhat less accentuated drop, and continue to decrease throughout the whole treatment. Even after 196 hours' treatment there will be some silver still passing into solution; and, at the moment of the discharge, about 30 per cent. of the undissolved silver in the tails could still be dissolved. This, however, could not be done with profit.

The attempt has been made to treat both sand- and slime-tailings with nitric acid, and then with *aqua regia;* and these tests have confirmed the results obtained by Mr. S. H. Pearse,[2] namely, that only a few cents in gold and about 0.2 oz. of silver per ton can still be brought into solution by such treatment. From the diagrams it is easy to see that, after the second wash, the gold-extraction comes practically to a stand-still, while the silver-extraction proceeds, though at a decreasing rate.

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[2] S. H. Pearse, *Transactions of the Institution of Mining and Metallurgy*, October 20, 1904.

After the second solution has been decanted, two other washes were given to the slime; and with the fourth wash the slime was pumped over to the deep settlers, which are iron tanks, 20 ft. deep and 34 ft. in diameter, where, gradually settling, it caked down to 39 per cent. of moisture. Then it was discharged into the creek.

In practice, however, it was found almost impossible to give a fourth wash to the slime, because the plant was overcrowded. Hence, it was necessary to pump over the slime with the third solution, thus discharging into the creek the completely treated, but insufficiently washed, slime.

Concerning the consumption of KCN, we notice, from the diagram, that it is very great at the beginning of each wash, by reason of the dissolution of the gold and silver and the complex action of the cyanicides. All the experiments show that there is some loss in cyanide every time a solution comes in contact with the ore, even when all the values have already been brought into solution; and the loss in cyanide is proportional to the strength of the solution used. Therefore, the values ought to be dissolved in the shortest time possible, so as to reduce the losses in cyanide to the first few strong solutions used.

When the dissolution is economically complete, the succeeding washes will be carried on with the sole purpose of washing out the values. The wash-water is certain to become enriched with cyanide (which, by the way, is necessary for the precipitation in the zinc-boxes); but the loss of cyanide in the wash-water will be small, owing to the weakness of the solution. It is obvious that the cyanide-loss by discharging the tailings will be similarly reduced.

2. *Preliminary Test No.* 2.—A second test was carried on contemporaneously with the one just described, and the results were almost identical. In this test, however, the first solution used was stronger and the gold-extraction more rapid. The pumping and aëration during the first wash were suspended for

12 hr. after the charge and solution had become thoroughly mixed, and then started up again for 13 hours. The renewed aëration seems to mark an acceleration in the gold-extraction, though the drop of the tail-values is very close to the limit of error in sampling and assaying. Aëration is indispensable for rapid extraction; but this fact does not involve, as a consequence, the necessity of aërating the pulp during the whole period of agitation. The solution will rapidly absorb the maximum of oxygen soluble in it, and after one hour's pumping it will retain sufficient air-bubbles in emulsion to act as a oxygen-storage for a certain length of time.

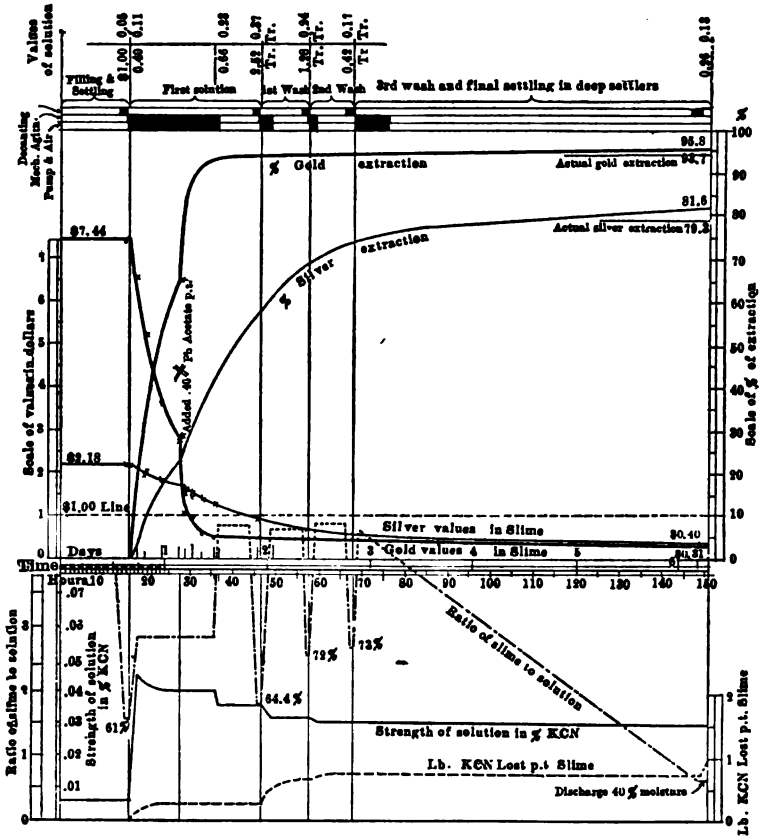
3. *First Modification of Slime-Treatment.*—The tests described in the preceding pages have shown us the marked action of the lead acetate on the rate of dissolution of the gold- and silver-values. Two further tests were made to determine whether it would be possible to complete the process of gold- and silver-solution during the first wash by adding chemicals at an earlier period of the treatment. The results of one of these tests are given graphically on Fig. 8.

In this test the lead acetate was added 11 hr. after the first cyanide solution had come in contact with the slime. During these 11 hr. the gold-extraction proceeds in a way similar to the one noticed in the test previously described. The silver-extraction is somewhat more rapid, a fact which may depend on some lead acetate being contained in the unprecipitated solution used as first wash. The addition of the lead acetate produces a sudden rapid extraction of the gold, and a far less accentuated one of the silver. In fact, the silver-values drop in an almost straight linear throughout the whole treatment, independently of whether the slime is agitated or settling.

It is easy to see from the diagram that the first wash could just as well have been cut off at the 35th hour; and the 12 hr. included between the 35th hour and the end of the first wash could have been used for giving an extra wash to the charge.

This would have saved about 17c. per ton, by lowering the values in solution in the final wash. After the 58th hour the slime was twice washed, as rapidly as the settling of the slime would allow, and then it was pumped over to the deep settlers with its fourth wash-solution.

Contemporaneously with this test, a second test was made in



Assay-returns marked by x.

Summary.

Quantity of tons treated,		61.5 tons.
Original assay-value,	Au.	$7.44
	Ag.	$2.18
Absolute gold-extraction,		95.8 per cent.
Absolute silver-extraction,		81.6 per cent.
Actual gold-extraction,		93.7 per cent.
Actual silver-extraction,		79.3 per cent.
Absolute total extraction,		92.6 per cent.
Actual total extraction,		90.4 per cent.
Assay-value of tails,	Au. dissolved,	$0.16
	Au. undissolved,	$0.31
	Ag. dissolved,	$0.05
	Ag. undissolved,	$0.40
KCN consumption, per ton of slime,		0.96 lb.
Chemicals: lead acetate per ton of slime,		0.46 lb.
Quantity of solution used,		643.6 tons.
Quantity of solution precipitated,		457.0 tons.
Total time of treatment in slime-tanks,		60.0 hours.

Notes.

Gold at $20.67. Silver at $0.50.

FIG. 8.—EXTRACTION TEST NO. 14, ON SLIME AT MILL NO. 2.
(June 16 to 22, 1905.)

which mercuric chloride was used instead of lead acetate. In this case the agitation and aëration with the centrifugal pump was dispensed with as much as possible. After the charge had been thoroughly mixed for one hour, the agitation was carried on for 29 hr. by merely keeping the pulp in rotation by means of the mechanical stirrers.

During the first 3.5 hr., after the solution came in contact with the slime, the dissolution of gold proceeded as rapidly as in the test previously described. The silver-extraction seems to be, as before, rather rapid. After 3.5 hours' treatment, mercuric chloride was added by suspending 16 lb. of $HgCl_2$ in a loosely-woven sack near the rim of the tank. The mercuric chloride, which was in broken pieces (some being as large as an egg), dissolved very slowly; after 10 hr. about one-third of it was still undissolved. The action of the mercuric chloride proved, however, to be exceedingly rapid, even with the small amount of it which can have dissolved during the first 3 hr. it was hanging in the tanks. Ten hours after the first lot of $HgCl_2$ had been added, a further addition of 2 lb. of $HgCl_2$ was made; but such addition only seems to have slightly affected the extraction of silver.

This test shows us that, during the 18 hr. following the 40th hour of treatment, the total useful work done was to extract only about 30c. in silver from the slimes. These 18 hr., therefore, were practically lost time; since the silver-extraction would have proceeded just the same if the slime had been settling; and they could have been used for giving an extra wash, which would have saved about 35c. per ton.

4. *Modified Slime-Treatment.*—The four tests described in the preceding pages give the evidence that, by using lead acetate or mercuric chloride at the beginning of the first wash, the extraction of the gold can be almost completed in 12 hr., and that 60 per cent. of the final extraction of the silver can be obtained during the same period of time.

The tests also show that the silver-extraction will continue during the following operation of washing-out the values by repeated settling and decanting, almost independently of the fact whether the slime is agitated or not.

It was, therefore, decided to modify the slime-treatment on slime-plant No 2. The outline of the treatment is as follows:—after decanting the mill-water from the already settled slime-charge, the pulp is stirred up and mixed with about its equal weight of unprecipitated solution, so as to bring the total ratio of solution to slime to about 2.5 to 3. While the solution is flowing into the tank, the final strength of the solution is brought up to from 0.045 to 0.05 per cent. of KCN, by hanging the necessary amount of NaCN in a sack just under the flow of clear solution entering the tank. When there is an excess of strong solution in the sand-treatment plant, as after heavy rains, it is usual to pump some strong solution into the slime-tanks, so as to bring up the strength of the weak solution. Lead acetate (0.4 lb. per ton of slime) is dissolved at the same time and by the same method.

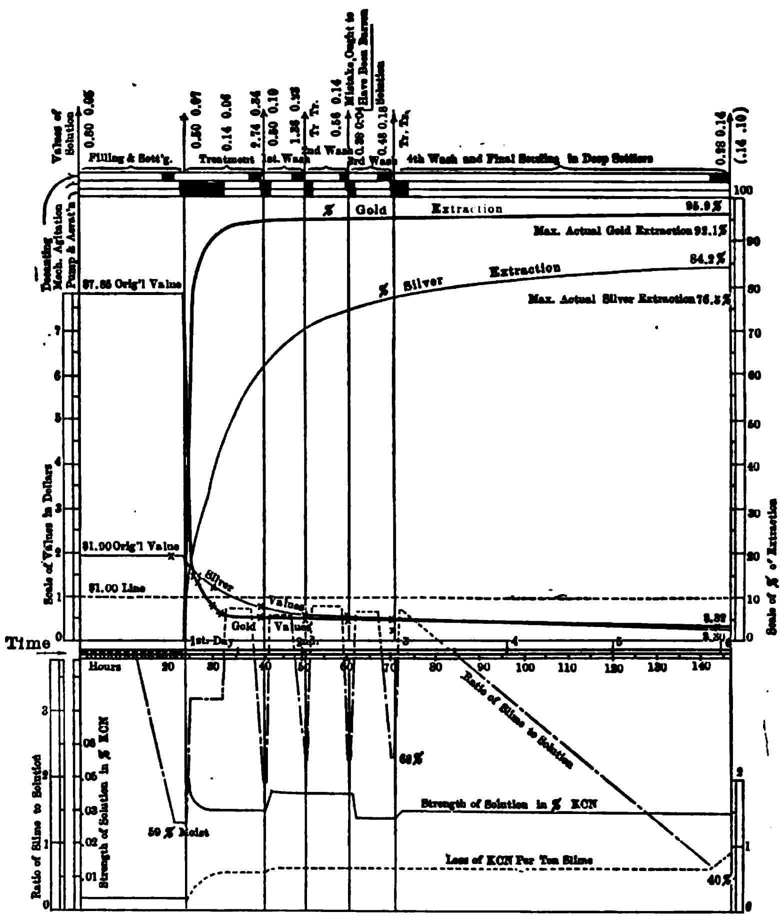
After the required volume of solution has been added to the charge, which takes about 1 hr., the double agitation by pump and stirrer is kept up for 7 hours. Then fresh, unprecipitated solution is added, so as to fill the tank completely. The agitation is then stopped, and the slime allowed to settle. After decanting the first solution as closely as possible, four additional washes are given to the charge as rapidly in succession as the settling of the slime will allow; and, with the last one, the pulp is pumped over to the deep settlers.

To diminish the amount of solution to be precipitated in the zinc-boxes, the first two solutions are unprecipitated solutions from the deep settlers. The value of such solution will only average 15c. in gold and a few cents in silver per ton, and therefore does not affect sensibly the final value of the last wash-solution.

It was customary at El Oro to keep the ratio of solution to slime as high as possible during the treatment. But the tests described in the preceding pages have proved that a rapid and good extraction can be obtained just as well when this ratio is as low as 2.5. The advantage of using a small bulk of solution during the first treatment is, that less cyanide and less lead acetate are needed to bring the solution to the desired degree of concentration.

Naturally, in washing-out the values, the ratio of solution to the slime has always to be kept as high as possible, to get a good extraction, because the capacity of the plant is not great enough to allow a great number of washes to be used.

In order to verify the efficiency of the modified treatment, a test was run on one of the slime-charges handled by the shift-bosses, and the results are given graphically in Fig. 9.



Assay-returns marked by x.

Summary.

Quantity of slime treated,	61.5 tons.
Original assay-value,	Au. $7.85 Ag. $1.90
Absolute gold-extraction,	95.9 per cent.
Absolute silver-extraction,	84.2 per cent.
Actual gold-extraction,	92.1 per cent.
Actual silver-extraction,	76.3 per cent.
Absolute total extraction,	93.6 per cent.
Actual total extraction,	98.2 per cent.
Assay-value of tails, Au. dissolved,	$0.30
Assay-value of tails, Au. undissolved,	$0.32
Assay-value of tails, Ag. dissolved,	$0.15
Assay-value of tails, Ag. undissolved,	$0.30
KCN consumption, per ton of slime,	0.90 lb.
Chemicals: lead acetate per ton of slime,	0.46 lb.
Quantity of solution used,	813 tons.
Quantity of solution precipitated,	459 tons.
Total time of treatment in slime-tank,	50 hours.

Notes.

Gold at $20.67. Silver at $0.50.

FIG. 9.—EXTRACTION TEST NO. 16, ON SLIME AT MILL NO. 2.
(June 26 to July 2, 1905.)

We shall only call the attention to the fact that the 4th solution used was, by mistake, an unprecipitated solution, assaying 38c. in gold and 10c. in silver. If such solution had been a precipitated, and therefore practically barren, solution, the values of the final wash would have been 14c. in gold and 10c. in silver, instead of 28c. in gold and 14c. in silver per ton.

In Table VIII. are given some data regarding the slime-treatment, showing the increased saving obtained during the months of July and August, as compared with the months of May and June, recorded in Table VII.

TABLE VIII.—*Data of Slime-Treatment, Showing Increased Economy During July and August,* 1904.

	May.	June.	July.	August.
Average gold value of slime-tails...	$1.150	$1.130	$0.840	$0.570
Average silver value of slime-tails.	0.810	0.790	0.440	0.340
Average gold value of last wash...	?	0.527	0.180	0.143
Cost of pumping and agitating......	0.610	0.465	0.234	0.206
Total cost of treatment...............	1.675	1.516	1.261	1.219
Total loss and expenses per ton of slime......	3.635	3.436	2.541	2.129

Preliminary tests have proved that lead chloride has the same effect on the rate of extraction as lead acetate. However, it has not been possible, up to this moment, to obtain quotations on the price of lead chloride sold in car-lots, or has it been possible to try the chloride on a working-scale.

Table IX. gives, in a condensed form, the cost of treatment per ton of slime, as well as some data which may be found useful for reference.

TABLE IX.—*Cost, per ton, of Slime-Treatment at Mill No.* 2 (1905).

	July.	August.
Separators, ...	$0.0252	$0.0199
Sand-wheel, ...	0.0221	0.0129
Tube-mills, ...	0.1507	0.2796
Precipitation, ...	0.2128	0.1943
Cyanide, ...	0.2202	0.1637
Circulation-pumps, ...	0.1358	0.1398
Agitators, ...	0.0983	0.0658
Solution-pumps, ...	0.0626	0.0637
Retorting and melting, ...	0.0700	0.0514
Labor, ...	0.2221	0.1792
Other items, ...	0.0417	0.0484
Total, ...	$1.2615	$1.2186

Data of Slime-Treatment.

	Per Cent.	
Moisture: Pulp flowing to treatment-tanks,	90	
Charge collected (1st settlement),	53	
Slime-tails discharged	40	
Charging: Average charge per tank,	76.4 tons.	
Time of collecting one charge:		
100 stamps, 40-mesh, 2.5 in. discharge, 1 tube-mill,	11 hr.	
100 stamps, 30-mesh, 2.5 in. discharge, 2 tube-mills,	9 hr.	
100 stamps, 30-mesh, 2.5 in. discharge, 3 tube-mills,	7 hr.	
100 stamps, 25-mesh, 2.5 in. discharge, 3 tube-mills,	5.5 hr.	
Sizing-Test: On 200-mesh (0.067 mm.),	from 5 to 12 per cent.	
Through 200-mesh (0.067 mm.),	from 95 to 88 per cent.	
Treatment-Tanks: Diameter,	34 ft.	
Height,	10 ft.	
Normal capacity,	10,000 cu. ft.	
Thickness of plate,	¼ and $\frac{3}{16}$ in.	
		Hours
Time: Agitation of first solution,		8
First settling,		8
Total time for each wash,		9.5
Total time for collecting, treating, washing, decanting, losses of time, shut-downs for each 76-ton charge (average, July, 1905),		78
Time for complete extraction of gold,		12
Time of agitation by pumps and stirrers,		14.25
Time of settling in deep settlers,		from 3 to 4 days.
Solutions and Chemicals: Strength of solution,	0.05 per cent. of KCN.	
Ratio of solution to slime (treatment),	2.5	
Ratio of solution to slime (washing),	5.0	
KCN consumption per ton of slime,	0.95 lb.	
Lead acetate used per ton of slime,	0.45 lb.	
Or mercuric bichloride per ton of slime,	0.20 lb.	
Lime used per ton of ore crushed,	12.0 lb.	
Assay-Values: Value of heads,		Au, $7.00–9.00 Ag, 1.50–2.25
Value of tails (unwashed),		Au, 0.40–0.70 Ag, 0.25–0.45
Value of mill-water,		0.50–1.00
Value of first solution decanting,		2.40–3.00
Value of last wash,		0.15
Gold-extraction,		91 to 92 per cent.
Silver-extraction,		75 to 80 per cent.
Value of precipitated solution,		trace
Agitation: h.p. for running one centrifugal pump,		14.6 h.p.
Total cost per hr. one centrifugal pump,	$0.76	
Cost of one centrifugal pump (San Francisco),	192.	
h.p. for running one mechanical agitator,		60 h.p.
Total cost per hr. for one mechanical agitator,	0.55	
Transmission-friction for agitation plant (about),		40 h.p.
Total cost per h.p-day,	0.46	

Labor per day (sand and slime):
- 3 shift-bosses on 8-hr. shifts.
- 6 native tanqueros (tank-men) on 12-hr. shift.
- 2 pump-men.
- 2 separator-men.
- 2 tube-mill men.
- 2 lime-feeders.

VIII. Sand-Treatment—Mill No. 2.

The sand, separated by the two spitzkasten of the plant, is elevated by a sand-wheel, 41 ft. in diameter, and flows to the sand-receivers, which are nine steel tanks, 22 ft. in diameter and 10 ft. in depth.

The sand is distributed by Butters' distributors, and settles promptly, while the mill-water overflows through slats, carrying away about 65 per cent. of the slime contained in the pulp entering the sand-receiver.

Since July 21st, a 6-ft. cone has been placed at the discharge of the sand-wheel, and the coarse sand is separated and returned to the tube-mills, while the fine sand overflows to the sand-receivers.

The legend of Fig. 2 shows the diagram of the average sand collected under the present conditions and with the stamps crushing through 25-mesh. It is to such a class of sand that the tests hereafter described refer to.

The specific gravity of the sand is 2.55; when collected in the sand-receivers it will settle, leaving 40 per cent. of the total volume as interstitial spaces. When the interstitial spaces are completely filled with water, the water in the sand is 21 per cent.; if allowed to drain for 18 hr. the sand will still retain from 14 to 15 per cent. of water. The weight of the dry sand settled in the sand-receivers is 160 tons of dry sand for 8 ft. 6 in. actual filling.

When the sand has been drained for 24 hr., it receives three strong solutions, averaging from 0.20 to 0.30 per cent. of KCN. Then it is excavated by a Blaisdell excavator, and conveyed by Robins belt-conveyors to the steel treatment-tanks, which are 40 ft. in diameter and 78 in. in depth, 66 in. of which are available for filling. The sand is distributed in these tanks by a Blaisdell distributor. Each treatment-tank can be filled to the rim, when it will contain 282 tons of sand at 24.5 cu. ft. to the ton. During the treatment, however, the sand will pack 10 per cent., and, at the end of the treatment, 22 cu. ft. of sand will weigh one ton.

The treatment consists in leaching the sand with a certain number of strong (0.3-per cent.) solutions, followed by a medium (0.15-per cent.) solution, and finally by a few weak (0.05-per cent.) solutions. When the treatment is completed, the tank is excavated and the sand conveyed to the dump. This is the outline of the treatment used up to August, 1905. To find out exactly what happens during the treatment, one charge of sand was followed closely throughout the whole process, and the results obtained are given graphically in Fig. 10.

The method of graphic representation used is similar to the one already explained for the slime. The scale of the ordinates (= time) had, however, to be reduced to 30 hr. per inch, in the original blue prints, which has been still further reduced in the illustrations given in this paper.

Another point in which the sand-diagram differs from the slime-diagram is, that each charge in the sand-treatment tank is composed of two sand-receiver charges. The first part of the diagram had, therefore, to be kept double, up to the moment in which the two sand-receiver charges were distributed in one sand-treatment tank. As this, however, brought a confusion of lines the data of per cent. extraction, KCN consumption, etc., were averaged, considering the two sand-receivers to be one unit-charge, not all parts of which had a synchronous treatment.

The curves, giving the gold- and silver-values of each separate sand-receiver charge, are, however, also given in dotted lines in the first part of the diagram.

1. *First Preliminary Test* (Fig. 10).—This test was run on a lot of 281 tons of sand, the composition of which was similar to the one given in Fig. 2, on page 89.

The charge was collected in two sand-receivers. The filling of receiver No. 1 took 20 hr.; the charge was allowed to drain 24 hr., then three washes of strong solution, amounting to a total of 0.48 tons per ton of sand, were percolated through the charge. The filling and treatment of the second sand-receiver, No. 3, followed by 20 hr. that of sand-receiver No. 1, and were kept as similar to it as possible. By reason of a shut-down, both sand-receivers had to wait an average of 48 hr. after receiving the third wash before being excavated. At the 132d hour the excavation of sand-receiver No. 1 began, and, as soon as completed, was followed by that of No. 3. The amounts excavated from the two sand-receivers were, respectively, 159.8 and 121.5 tons. The average of the assay-value, percentage-extraction, etc., were figured out according to the relative tonnage of the two sand-receiver charges.

a. Gold- and Silver-Values.—The gold-values for both sand-receiver charges begin to decrease as soon as the first strong solution comes in contact with the sand, in a way similar to the one noticed for the slime, though the rate of extraction is very much smaller.

A sudden drop in values begins to take place only at the 132d hour, at the moment when the sand begins to be excavated, and therefore aërated.

From this moment on, the curve representing the gold-values assumes again a marked parabolic shape, the rate of extraction decreasing as the undissolved gold-values decrease.

The three main factors in the rate of extraction are: the diameter of the undissolved gold grains, the strength of the solution, and the rate at which the solutions follow each other. It is very difficult to give to the assay-returns their true value, as the samples for assay cannot be relied on as closely as was possible with slime. The curve, therefore, had to be drawn, following closely the assay-return.

We can notice, however, a certain drop of the gold-values at the 6th wash, probably caused by the fact that a strong solution was followed immediately by a weak solution. Any sudden change in the strength of the solution will produce an increased rate of gold-extraction. We see, from the diagram, that the gold-extraction was completed at the 250th hour, and that, from that moment, not one cent more was extracted during the 9 following days of treatment.

The silver behaves in a very different way from the gold. We can say, practically, that the values decreases proportionally to the time, and independently of the strength of the solution or any other factor, though actually, at the beginning, the rate of extraction was somewhat more rapid. The addition of lead acetate to the charge had a slight beneficial effect on the silver.

b. Values of Drained Solution.—The gold- and silver-values in the solution draining off from the sand are represented in the diagram by dotted curves.

Naturally, the increase in value of the solution is a result of the extraction from the sand. It is worth noticing that the maximum of the values of the draining solution always follows, in about 50 hr., the cause which produced an increased rate of extraction. In fact, we can notice on the diagram three maximums both for the gold- and for the silver-values of the solution. The first and most important maximum occurs 50 hr. after the excavation and aëration of the sand has taken place, the values of the solution rising up to a maximum of $14 gold and $2 silver. Then the values drop rapidly, to rise again slightly on the 12th day, or 50 hr. after two strong washes, alternated with a medium wash, have been given to the charge. Finally, during the 14th and 15th day we have again a rise in values, 50 hr. after another batch of strong solutions, following two weak solutions, was run on the sand.

The reason that the values of the solution follow the rate of extraction with a period of 50 hr. delay, is easily understood if we consider that about 40 or 50 tons of solution are kept back as moisture in a 300-ton charge of sand. Each time we add a wash of 15 tons of solution on the top of the sand-charge, we shall displace 15 tons of solution which were previously retained as moisture.

We can, therefore, imagine the 50 tons of moisture in the sand to be retained in four strata corresponding to four successive washes, and each time we add a new wash one stratum of moisture displaces the other.

c. Cyanide Solution.—The diagram shows that the strengths of solution used in the treatment were most irregular. This was done intentionally, in order to ascertain what bearing the strength of the solution, and the alternations of strong and weak solutions, had on the rate of extraction.

d. Conclusions.—The test just described leads to the following conclusions:—

1. The rate of extraction is dependent upon the strength of the solution and the speed at which the washes follow each other.

2. The extraction by strong solution is small for the tightly-packed sand in the sand-receivers.

3. The aëration effected by excavating the sand has a very great influence on the rate of extraction, at least for a certain length of time.

4. The gold-extraction will reach its maximum in a comparatively short time, and long before the whole of the soluble silver has been extracted.

5. The silver-extraction will continue in an almost straight line, and apparently unaffected by the strength of solution and the rate of washing.

6. Lead acetate, in small amounts, will not affect the gold-extraction, but will be beneficial to the silver-extraction.

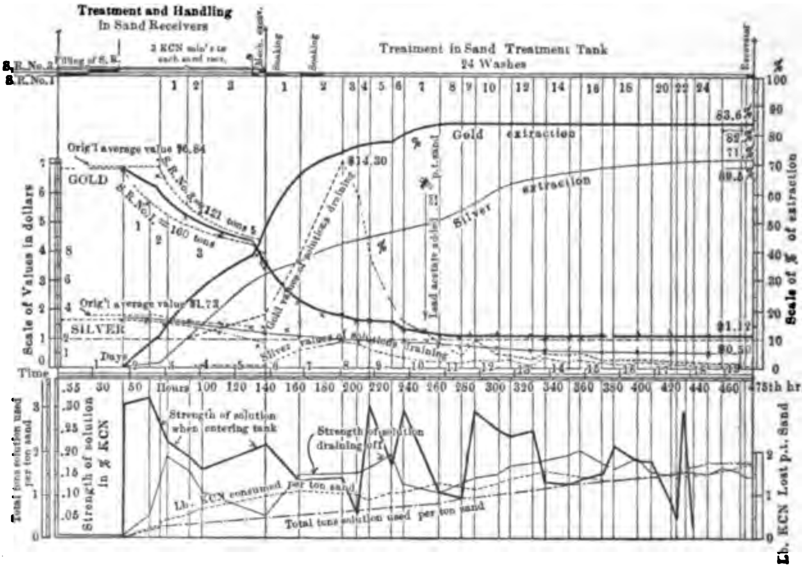
7. Cyanide-consumption is rapid during the first 5 days (56.4 lb. of KCN per 24 hr.), after which the consumption becomes almost constant during the 13 following days (10.8 lb. of KCN per 24 hr.).

2. *Second Preliminary Test.*—The test previously described was followed by a second, the results of which are given graphically in Fig. 11. The main point aimed at in this test was to see whether it would be possible to increase the rate of extraction by excavating the sand as soon as it had received the first two preliminary strong solutions, and then giving to the sand a number of small washes in rapid succession.

From the foregoing, it is evident, that, for the sand, the extraction depends chiefly upon fine grinding. The soluble gold is easily brought into solution, and so is also the silver. The only improvement which can be made in the sand-treatment is to reduce expenses and losses, and to shorten the time of treatment required for the dissolution of the values, in order to increase the capacity of the plant or to get more time for dissolving the silver and for washing-out the dissolved values.

The diagrams on Fig. 11 can be easily understood after what has been said for test "T" (Fig. 10). The following facts, however, deserve attention.

The undissolved gold-values show three marked drops; the first, after the 110th hour, when the first (3d) solution was run on the sand after it had been aërated during the transfer from the sand-receivers to the treatment-tank; a second drop takes place after the 131st hour, and a third one after the 163d hour, both due to the fact that a strong solution was followed by a



Assay-returns marked by x.

Summary.

Quantity of sand treated,		281.5 tons.
Original assay-value,		Au. $6.84 Ag. $1.73
Absolute gold-extraction,		83.6 per cent.
Absolute silver-extraction,		71.0 per cent.
Actual gold-extraction,		82.9 per cent.
Actual silver-extraction,		69.5 per cent.
Absolute total extraction,		81.1 per cent.
Actual total extraction,		80.2 per cent.
Assay-value of tails,	Au. dissolved,	$0.05
	Au. undissolved,	$1.12[a]
	Ag. dissolved,	$0.02
	Ag. undissolved,	$0.50
KCN consumption, per ton of sand,		1.69 lb.
Chemicals: lead acetate per ton of sand,		0.22 lb.
Quantity of solution used per ton of sand,		1.74 tons.
Quantity of solution precipitated,	(1.74 × 281.5)	489.81 tons.
Total time of treatment,		475 hours.
Time taken for dissolution of gold,		196 hours.

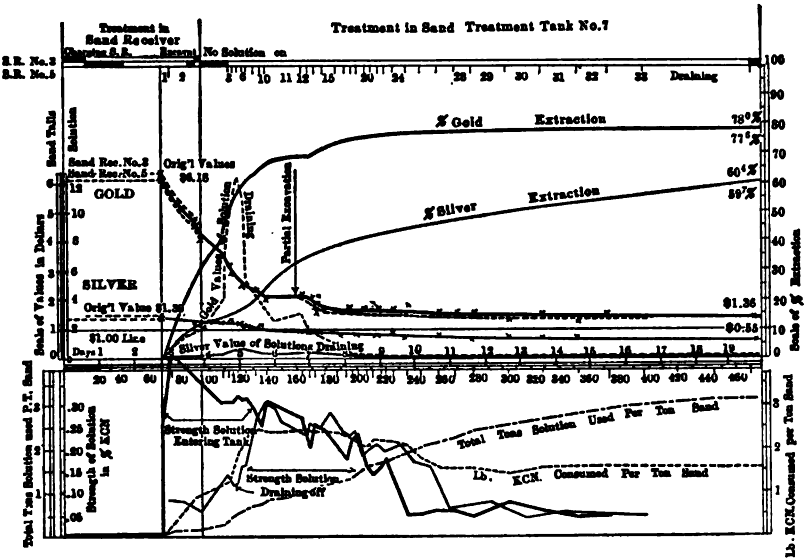
[a] Average of 32 assays (4 A. T. each).

Notes.

Gold at $20.67. Silver at $0.50.

FIG. 10.—EXTRACTION TEST "T" ON SAND AT MILL NO. 2.
(July 1 to 20, 1905.)

[40]



Assay-returns marked by x.

Summary.

Quantity of sand treated, ...		236 tons.
Original assay-value, ...		Au. $6.18 Ag. $1.39
Absolute gold-extraction, ...		78.0 per cent.
Absolute silver-extraction, ...		60.4 per cent.
Actual gold-extraction, ...		77.6 per cent.
Actual silver-extraction, ...		59.7 per cent.
Absolute total extraction, ...		74.9 per cent.
Actual total extraction, ...		74.4 per cent.
Assay-value of tails, . . .	Au. dissolved, . . .	$0.03
	Au. undissolved, . .	$1.35
	Ag. dissolved, . . .	$0.01
	Ag. undissolved, . .	$0.55
KCN consumption, per ton of sand, ...		1.54¼lb.
Quantity of solution used per ton of sand, ...		3.1 tons.
Quantity of solution precipitated, ...	(236 × 3.1)	731.6 tons.
Total time of treatment, ...		478 hours.
Time taken for dissolution of gold, ...		120 hours.

Notes.

Gold at $20.67. Silver at $0.50.

FIG. 11.—EXTRACTION TEST "F" ON SAND AT MILL NO. 2.
(August, 1905.)

somewhat weaker one, and then again by a third solution of the same strength as the first one.

In the 280 hr. following the 190th hr., not more than 14c. gold per ton of sand was dissolved, and the greatest part of it was dissolved in the first 72 hours.

The silver shows a fact noticed in several tests, namely, that the extraction begins to become more rapid as soon as the dissolution of the gold is almost complete. This may be due either to the fact that the cyanide will dissolve gold in preference to silver as long as there is gold still to be dissolved easily, or to the fact that some time must elapse before the reaction, causing the dissolution of the silver minerals, will begin.

At the 160th hr., one-eighth of the tank was excavated by hand to aërate one portion of the sand. The sand was thrown out on a platform and then returned to its place. Subsequent to this moment, samples were taken continuously from both the re-arëated part of the tank and from the untouched part. The assay-returns (see dotted line near the gold-curve) showed that the renewed aëration caused an increased rate of extraction; but such increase was small, and after a few days the gold-value of the sand in both parts of the tank had again become practically the same. This operation was repeated on a second tank with the same results.

3. *Modified Treatment.*—In consequence of the results given by the two tests described above, it was decided to modify the sand-treatment as follows:—

The sand collected in the sand-receivers was allowed to drain for 24 hr., when it was excavated and conveyed to the leaching-tanks without receiving any preliminary treatment.

The preliminary treatment was first adopted with the idea that it would be useful to have the sand-grains moistened with strong cyanide solution at the moment when the aëration by excavating takes place. Experiments, however, have proved that the extraction is just as rapid if the sand is treated by cyanide only after the aëration has taken place.

On the other hand, the preliminary treatment presents two drawbacks. The first is, that it is impossible to prevent some of the strong cyanide solutions used as preliminary washes to pass into the mill-water (see page 86) for two reasons: (1) the drainage-plugs and valves will leak, or may be left open by mistake; (2) after excavating, the 6-in. filter-bed of coarse sand, which is left to cover the cocoa-mat filter, will retain 2.8 tons of cyanide solution as moisture, which, as soon as the sand-receiver begins to receive a new charge, will be completely washed out into the mill-water.

The second drawback is, that, after giving the preliminary washes, it is necessary to lose 24 hr. in allowing the tanks to drain before starting to excavate them.

A second point in which the treatment has been modified is, that the first 16 washes given to the sand are alternating strong and medium washes, and are followed by as large a number of weak washes, at 6-hr. intervals, as the capacity of the plant may allow or as may be considered convenient.

By these means the time necessary for the almost complete dissolution of the soluble gold (to within 20c.) has been at present reduced to about 90 hr., while formerly it took about 200 hr. to obtain the same result.

Other tests, not related in this paper, also prove that cyanide solutions, containing from 0.15 to 0.20 per cent. of KCN, will give as good and as rapid an extraction as a 0.30 per cent. of KCN solution. Therefore, the strength of the strong solution has been reduced to 0.25 per cent. of KCN, with the result that the cyanide consumption has been diminished.

We may say at this point, that, lately, a large amount of fine sand has been sent over with the slime to the slime-treatment tanks. On several occasions as much as 4 per cent. on 150-mesh and 9 per cent. on 200-mesh sand was mixed with the slime. On separating and assaying these sands, after treatment by agitation with 0.05-per cent. KCN solution, it was found that the extraction from the sands had been just as good as if they had been leached with 0.30-per cent. KCN solution in the leaching-tanks.

Extraction-tests, made on the sand treated by the modified treatment, show that the curve representing the gold-value of the sand is regular and continuous, and can be very closely represented by a parabola.

In the light of all that has been said in this paper on the problem of extracting the gold- and silver-values from the ore by cyanide, we see that the problem chiefly consists in the mechanical reduction of the ore to the finest possible state of division. There are no serious chemical problems to be resolved; and all the difficulties are on the mechanical side. The treatment of the slime, which, but a few years ago, seemed to present serious difficulties, is being gradually perfected; and the time will probably come when the sliming of the ore to the maximum point, economically practicable, will be the main object of a number of plants, as at present it is at El Oro.

The itemized cost and data of treating the sand at Mill No. 2, is given in Table X.

TABLE X.—*Cost, Per Ton, of Sand-Treatment at Mill No.* 2.

	July.	August.
Separators,	$0.0227	$0.0250
Elevators,	0.0400	0.0322
Tube-mills,[a]	0.2045	0.5286
Precipitation,	0.1918	0.2430
Conveyors,	0.0736	0.0561
Excavators,	0.0521	0.0855
Cyanide,	0.3593	0.2755
Solution-pumps,	0.0141	0.0159
Retorting and melting,	0.0631	0.0643
Other items,	0.1146	0.1635
Total,	$1.1358	$1.4866

[a] Tube-Mill No. 5 started August 1st, and the first cost of 14 tons of pebbles was charged to the month of August.

Data and Sand-Treatment.

Moisture of Sand: Well drained,	from 14 to 15 per cent.
Charging: Charge collected in sand-receiver,	150 tons.
Charge treated in treatment-tanks,	285 tons.
Time for collecting 300 tons,	48 hr.
Sizing-Test: On 100-mesh,	from 8 to 12 per cent.
Through 100- on 200-mesh,	from 60 to 65 per cent.
Through 200-mesh,	from 20 to 28 per cent.
Sand-Receivers (nine): 22 ft. in diameter by 10 ft. (0.25-in. bottom, $\frac{3}{16}$-in. body).	
Maximum capacity,	160 tons.
Sand-Treatment Tanks (twelve): 40 ft. in diameter by 6.5 ft. ($\frac{1}{4}$-in. bottom, $\frac{3}{16}$-in. body).	
Capacity,	285 tons.
Treatment: 16 alternated washes, medium and strong,	4 days.
16 weak solutions (more, if possible),	4 days.
Minimum time for treating, draining and discharging,	9.5 days.
Average length of treatment,	18 days.
Time for complete gold dissolution (to within 20c.),	90 hr.
Time for complete silver dissolution,	17 days.

Average rate of silver dissolution for a 300-ton charge per day,		$16.30
Average rate of silver after 10 days of treatment,		$6.60
Strength of solutions	Weak,	from 0.03 to 0.05 per cent. of KCN.
	Medium,	from 0.10 to 0.15 per cent. of KCN.
	Strong,	from 0.20 to 0.25 per cent. of KCN..
Total tons of solution per ton of sand,		from 2 to 8 tons.
KCN consumption per ton of sand,		1.5 lb.
Assay-Values: Values of heads,		gold, from $6.00 to $8.00 silver, from 1.30 to 1.80
Value of tails,		gold, from 1.10 to 1.80 silver, from 0.50 to 0.70
Probable economic limit to which the tails may be brought by fine grinding,		gold, 0.90 silver, 0.40
Value of Solution:		
Precipitated strong solution,		gold, from $0.03 to $0.15
Precipitated weak and medium solution,		gold, trace.
Maximum of solution draining off,		gold, from $9.00 to $14.00 silver, from 0.50 to 1.50
Lost solution draining off,		gold, from 0.10 to 0.35 silver, from 0.10 to 0.15
Excavators and Conveyors:		
Average rate of excavating sand-receivers by Blaisdell excavator, per hour,		from 90 to 100 tons.
Average rate of excavating per 40 ft. of treatment tanks,		from 90 to 100 tons.
Total cost of excavating (twice) per ton,		from $0.05 to $0.08
Total cost of conveying (twice) per ton,		from 0.05 to 0.07

IX. Precipitation and Precipitates.

1. *The Zinc-Room.*—The gold- and silver-bearing solutions, which are drained or decanted from the treatment-tanks, are collected in intermediate storage-tanks. The tanks receiving the solutions from the slime-treatment are provided with a filter-bottom to prevent the slime from passing into the zinc-boxes.

From the intermediate tanks the solutions flow to a zinc-room, 137 ft. by 73 ft., designed for precipitating the solutions from both the old and the new plant.

There are two rows of steel boxes, 30 of which are 16.5 ft. long, having five compartments; the available zinc space of each compartment is 4 ft. wide, 3 ft. long and 2 ft. deep; 14 other zinc-boxes, 16.5 ft. long, having 6 compartments 30 in. by 30 in. by 24 in. deep, were obtained from the 9 compartment boxes of the old precipitation plant. All the boxes are provided with 0.25-in. mesh screens set 4 in. from the bottom.

The boxes are set on a platform at 8 ft. from the floor; the precipitated solutions flow into central launders and pipes which lead to the sumps.

The boxes are equipped with bottom discharge-valves, which open into U-shaped steel launders, leading to a central launder, which empties into the 2 clean-up iron tanks, 6 ft. square and 4 ft. deep.

The precipitate is screened before entering the tanks, and from there it is pumped to a 24-in. Stillwell-Bierce filter-press, holding fifty 1-in. frames.

The acid treatment is done in two redwood tanks, 7 ft. in diameter and 4.5 ft. deep, lined with lead. The tanks are equipped with mechanical agitators, run by a 3.5-h.p. electric motor, which also runs a small blower for carrying-off the acid fumes through flues.

The wash-water and precipitate from the acid tanks are run into a cement sump, 7 ft. in diameter and 5 ft. deep, and a 4-in. by 6-in. bronze water-end duplex pump forces the precipitate into a 24-in. Johnson filter-press, holding 24 frames.

Four steam-jacketed drying-cars, set on masonry pillars, are used in case of accident to the filter-press, from which it might be necessary to take out soft cakes. One drying-car on wheels can be conveyed to any point of the room, and is run under the filter-presses when these are opened, so that the cakes fall directly into the car.

The entire floor of the zinc-room is cemented (6-in. masonry, 3 in. of concrete, and 1 in. of cement), and slopes from all sides to a cement sump at the center of the room.

On one side of the room are 6 melting-furnaces, built in one row. They are 26 in. in diameter and 4 ft. deep; the bottom for a distance of 6 in. tapers down to 19 inches. The furnace flues open into a common flue which leads to a large dust-chamber, 10 ft. by 5 ft. by 21 feet. The stack is 40 ft. high, and the draught is helped by a steam-jet from an 0.25-in. nozzle.

On the outside of the building is a track about 10 ft. above the level of the zinc-room floor, which offers the facilities of unloading the zinc shaving directly onto the floor where the precipitation-boxes are; this track is also used for emptying the sulphuric acid in the lead storage-tank, as well as for the coke in a coke-bin near the furnaces.

2. *Precipitation of Solutions.*—The solutions from the two plants are of equal strength, but the solutions from the new plant are lower in value, since a greater amount is required to wash out

the dissolved values from the very fine sand than from the comparatively coarse sand of the old plant.

There are 44 iron precipitation-boxes, of which 4 are used for strong solution (from 0.2 to 0.3 per cent. of KCN), 4 for medium solution (0.1 per cent. of KCN), and 36 boxes for weak solution (0.03 per cent. of KCN).

The average rate of flow through the boxes per cu. ft. of zinc shavings per 24 hr. are: strong solution, 1 ton; medium solution, 1.1 tons; and weak solution, 1.4 tons.

The precipitation of the weak solution is assisted by a "drip" of fresh 2.5-per cent. cyanide solution at the head of the box, added at the rate of 16 lb. of KCN per 24 hr., for the 36 weak-solution boxes.

Practically, all the precipitation takes place in the first 3 compartments, the last one being intended only to retain any precipitate which might flow off when the box is started up after a clean-up. The fresh zinc in this last compartment indicates whether the box is working properly or not.

Table XI. shows the manner in which the precipitation of the gold and silver takes place in the 5 compartments, as well as the variation of the strength of the solutions flowing through the compartments.

TABLE XI.—*Precipitation of Gold and Silver in the Zinc-Boxes.*

Precipitation and Cyanide Consumption in Zinc-Boxes.

	Head 1st Comp.		Head 2d Comp.		Head 3d Comp.		Head 4th Comp.		Head 5th Comp.		Tail 5th Comp.	
	Au.	Ag.	Au.	Ag.	Au.	Ag.	Au.	Ag.	Au.	Ag.	Au.	Ag.
	$	Oz.	$	Oz.	$	Oz.	$	Oz.	$	Oz.	$	Oz.
Values of sol[a]....	4.54	1.25	1.14	0.47	0.42	0.18	0.15	0.08	0.11	0.07	0.07	0.04
Cumul. % ext......	......	......	75.0	62.4	90.8	85.6	96.7	93.6	97.6	94.4	98.4	96.8
Strength of sol...	0.210 %		0.202 %		0.198 %		0.198 %		0.198 %		0.196 %	
Values of sol[b].....	3.00	0.62	1.00	0 26	0.18	0.06	0.01	0.01	tr.	tr.	......	......
Cumul. % ext......	......	......	66.6	58.1	94.0	90.3	99.6	98.4	100.0	100.0	100.0	100.0
Strength of sol...	0.128 %		0.124 %		0.122 %		0.116 %		0.112 %		0.106 %	
Values of sol[c].....	0.62	0.33	0.86	0.18	0.25	0.17	0.11	0.04	tr.	tr.	......	......
Cumul. % ext......	......	......	41.8	45.4	59.6	48.4	82.3	87.9	100.0	100.0	100.0	100.0
Strength of sol...	0.054 %		0.052 %		0.050 %		0.048 %		0.046 %		0.046 %	

[a] Strong Solution. [b] Medium Solution. [c] Weak Solution.

3. *Clean-up.*—When the solutions are running regularly the strong boxes are cleaned every 4 or 5 days, the medium boxes about every 6 days and the weak boxes every 10 days. If, for any reason, any of the boxes are not working properly, the first two compartments are given a preliminary cleaning.

The general cleaning of the boxes is carried out as follows:—the flow is shut off and all of the zinc is taken out of the 1st, and piled up on the 3d, 4th and 5th compartments. The solution and precipitate are then drawn out of the 1st compartment and the screen cleaned and put back. All the zinc of the 1st compartment is then washed in the solution in the 2d compartment and replaced in the 1st. Great care is taken to stretch out the bundles of zinc-shavings and to pack them in the boxes in alternated layers running lengthwise and crosswise to the boxes. By this arrangement the solution, flowing through the zinc, finds everywhere an equal resistance, and has no tendency to channel. The bottom of the 1st compartment is packed with a 6-in. layer of good, firm zinc, on top of which are placed the zinc-shorts that have been returned from the clean-up screens; finally, the balance of the space is filled with fairly firm zinc.

The other compartments are treated in a similar way. The zinc-shavings are thus slowly moved from the last compartment towards the head of the box, and the fresh zinc is always added in the last compartment. Except on a monthly clean-up, the last compartment is left intact to act as a filter. No precipitate is carried over if the boxes are washed thoroughly and the precipitation started slowly.

The precipitate is discharged from the bottom of the boxes into launders and collected in two clean-up tanks. Before entering the tank the precipitate is screened through a 50-mesh screen divided in three compartments. The heavy zinc-shorts settle in the center compartment, while the solution and the fine precipitate overflow on the sides and pass through the two other compartments. The precipitate settles rapidly in the tank, and the clear solution is pumped through the filter-press.

When all the boxes are cleaned and enough precipitate is collected in the tank to make a "cake," it is stirred up and the pump put to a moderate speed, which is not changed until the press is full with a hard cake. The pressure-gauge usually shows about 60 pounds. Steam is now gradually turned into the press until it begins to blow out of all the drainage-cocks. It takes from 0.5 to 1 hr. to fill the press, and 0.5 hr. to dry it out with steam. The press is allowed to cool for an hour, and then it is opened, the cakes dropping into the drying-car. If the cakes still contain too much moisture for briquetting, they are further dried, mixed with flux, then briquetted and melted.

The zinc-shorts, which pass a 0.25-mesh screen and are retained on the 50-mesh screen at the clean-up tank, are sent to the acid tanks, where they are kept for the acid-treatment.

The sulphuric acid, diluted in the proportion of 1 of acid to 4 of water, is added to the zinc in small quantities at a time. The mechanical agitator keeps the zinc from settling.

After all the zinc has become dissolved, three or four washes of hot water are given to the residues, and the whole siphoned into a small cement sump or pumped direct to the filter-press, as previously explained, and handled in the same way as the screened precipitate.

Eight natives, working 9 hr., can clean up and wash all the zinc from 18 large and 3 small boxes. In one operation, 26,400 lb. of zinc-shavings are washed by 8 men; the precipitate, amounting to 1,760 lb., being handled automatically from boxes to drying-car.

The monthly output consists of about 70 bars of bullion, each bar weighing 1,000 ounces.

4. *Screened and Acid Precipitate.*—The screened precipitate, after coming from the filter-press, contains about 15 per cent., and the acid precipitate about 25 per cent. of moisture. The precipitate is taken out of the press while still hot, allowed to dry during the night, and then mixed with 18 per cent. of ground borax-glass, 8 per cent. of sodium carbonate, from 6 to 8 per cent. of sand and 8 per cent. of lime.

The analyses of the screened precipitate and the acid precipitate are as follows:—

	Screened Precipitate.	Acid Precipitate.
Gold,	7.66	4.58
Silver,	47.70	23.99
Copper,	1.11	1.98
Lead,	......	4.00
Zinc,	12.99	7.79
Silica,	6.06	11.90
Iron, Aluminium,	3.03	2.12
Arsenic, Antimony,	none	0.41
Lime,	9.67	9.22
Sulphur,	......	9.94
Not determined,	11.78	24.07
Total,	100.00	100.00

On the average, the screened precipitate will yield 65 per cent. of bullion, while the acid precipitate will yield 32 per cent. of bullion, the lower percentage of the latter being largely due to the presence of calcium sulphate, which is hard to wash out entirely.

The copper, which is contained in the ore in very small quantities, gradually concentrates in the weak boxes. There is never enough of it in the solution to interfere with the precipitation of the gold and silver.

The bullion from the acid precipitate is always higher in fineness than that from the screened precipitate, because the gold, 61 per cent. of which precipitates in the first compartment, clings to the zinc-shorts more firmly than does the silver, which precipitates in a loose form and is chiefly collected with the screened precipitate.

During the last six months the average fineness of the bullion obtained from the screened and acid precipitates was:—

	Bullion from Screened Precipitates.	Bullion from Acid Precipitates.
	Fineness.	Fineness.
Gold	133.0	193.06
Silver	767.4	696.94
Total	900.4	890.00

The analysis of the bullion gave—Gold, 12; silver, 77.02; copper, 1.98; lead, 4.46; zinc, 32; silica, nil; iron and alumina, 0.35; total, 96.13 per cent.

Briquetting Precipitates.—The briquettes are made by a small upright machine run by compressed air. The cylinder is 14 in. and the briquette mold 2⅞ in. in diameter. Under an air-pressure of 80 lb. the briquettes are compressed at a pressure of 2,000 lb. per sq. in.; but generally a pressure of 40 lb. of air is sufficient. In some cases, if a higher pressure be used, the briquettes will break in half when forced out of the mold.

The machine is fed automatically by a plunger-feed, which is at the bottom of a V-shaped hopper. The briquette is made by the down-stroke of the plunger, and is returned to the top of the mold by a return plunger, which is connected to the piston-rod by side rods.

Two men can handle the machine and make 10 briquettes a minute. Much experimenting showed that the best binder was 8 per cent. of slacked lime, moistened by a saturated solution of borax-water, and added to the flux. The briquettes do not "dust," even if they get chipped in handling. If borax-water is used alone the precipitate must first be dried. Using lime, the precipitate should contain about 10 per cent. of moisture.

Crude petroleum answers fairly well as a binder, but it contains carbon, which, during the melting, reduces zinc and other metals, and produces a base bullion. Briquettes, 3 in. thick, average 2 lb. in weight.

6. *Melting.*—On the day of melting, the fires are started by the night-man towards 5 or 6 a.m., and as soon as the bottom of the crucible becomes dull red it is filled with the damp briquettes. In from 60 to 90 min. the briquettes in the bottom begin to melt, and, as the charge sinks in the crucible, fresh additions are made as long as there is no danger of getting the damp briquettes added directly into the molten mass, because, if this were done, the charge would spit and throw the slag and metal out of the crucible.

The crucibles are removed from the furnace by an air-lift. The tongs holding the crucible are suspended by a bail, hinged in such manner that the crucible, when two-thirds full of metal and slag, can easily be tilted.

It takes from 3.5 to 4 hr. to melt down and pour one charge. Five furnaces at one time are used for refining precipitate, and one for bullion; and one man with two stokers melt and refine 2,000 lb. of precipitate in 10 hours. The bullion and slag together are poured into conical molds, and, after solidification, the slag is broken off, and the bullion remelted in No. 100 and No. 200 crucibles, from which a dip-sample is taken. The bullion is poured into bars, each weighing about 1,000 ounces.

7. *Slags.*—The slag obtained from the smelting of the precipitate is sorted; the center part of the slag cones is remelted in a special cupola furnace, while the outer shell, as well as the slag from the top of the bullion bars, is remelted with from 5 to 10 per cent. of litharge-slag from the assay-office. The slag so remelted, assaying about $10 in gold, and from 15 to 20 oz. of silver per ton, is added to the charge that goes to the cupola furnace.

The ashes, sorted and screened to separate them from pieces of coke and clinkers, are mixed with lime and water, made into cakes and allowed to dry. These ash-cakes are also melted in the cupola furnace.

The cupola furnace, which has been in operation only a few times, is proving to be a success; the blast used has been compressed air, but, as it was not easy to control the fire by such means, arrangements are being made to use a small blower.

The slag from the furnace assays from $3 to $5 in gold value and 5 oz. of silver per ton. Data concerning the flue-dust are not, as yet, available. A sample swept from the floor of the dust-chamber assayed $210.90 in gold and 90 oz. of silver per ton, while a sample of flue-dust from the chimney of the old melting-furnaces assayed $372.06 in gold and 200 oz. of silver per ton.

A part analysis of the slag from screened precipitates gave:—Gold, $24.38, and silver, 18.0 oz. per ton; copper, trace; lead, 1.05; zinc, 1.13; silica, 20.60; iron and alumina, 4.18; and lime, 7.60 per cent.

8. *Cutting the Zinc.*—The zinc-sheets, which are from 6 to 7 ft. long and from 3 to 4.5 ft. wide, are cut on a machine-lathe. They are wound on a wooden mandrel, about 14 in. in diameter and a little longer than the width of the sheets. The lathe is geared to 200 rev. per min., and the cutting-tool moves at a speed of 0.62 in. per minute. One man and a boy will cut from 1,000 to 1,500 lb. of zinc-shavings in 9 hours. The zinc-shavings are stretched out in beds, and then rolled up in shape of bales and kept in stock.

9. *Cost.*—Exact figures for the cost of precipitation in the new zinc-room are not, as yet, available.

In the old mill, during the last six months, the average number of tons crushed per month was 10,380 tons. The cyanide-plant produced, per month, 29,859 oz. of bullion, averaging a total fineness of 889, or 4,030.35 oz. of fine gold, and 26,533.6 oz. of fine silver.

The cost of precipitating and melting, per ounce of bullion produced, and per ton of ore crushed, are:—

Precipitation.

	Cost per Oz. of Bullion.	Cost per Ton of Ore Crushed.
Labor,	$0.0094	$0.0272
Zinc,	0.0233	0.0767
Repairs, supt. and light,	0.0059	0.0169
Total,	$0.0386	$0.1208

Melting.

	Cost per Oz. of Bullion.	Cost per Ton of Ore Crushed,
Labor,	$0.0051	$0.0147
Chemicals,	0.0061	0.0175
Crucibles,	0.0034	0,0100
Fuel,	0.0027	0.0077
Repairs, supt. power and light,	0.0039	0.0113
Total,	$0.0212	$0.0612

	Per Oz. of Bullion.	Per Ton of Ore Crushed.
Zinc-consumption,	0.36 lb.	1.21 lb.
Sulphuric acid,	0.05 lb.	0.14 lb.

[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

Blast-Furnace Practice.*

A Discussion of the papers of Mr. James Gayley, on "The Application of the Dry-Air Blast to the Manufacture of Iron," and of Mr. J. E. Johnson, Jr., on "The Physical Action of the Blast-Furnace," by Mr. John Birkinbine, Philadelphia, Pa.

Mr. Gayley was not the only blast-furnace manager investigating the possibilities of dry air as applied to the smelting of iron-ores, and I understand he makes no claim to such distinction. It was my privilege to be familiar with some of the earlier efforts in this direction, and the persistency with which Mr. Gayley has followed the subject. Whatever, therefore, may come from the practical application of dry air, may be credited to protracted investigation, and a conscientious study of the possibilities.

This special feature of blast-furnace economy is an evidence of the general policy which has done so much in the last quarter of a century to make the smelting of iron-ores more than a mere "rule of thumb." Within my professional experience, the manager who desired a greater output would construct a furnace of larger dimensions, and with more powerful equipment; but, in later years, improvements have not been confined to physical conditions, but have resulted from chemical research and the perfection of mechanical appliances. Mr. Johnson's paper is a valuable contribution to these researches.

Former blast-furnace records covered the number and size of charges, the pressure and temperature of blast, etc., as taken several times a day. Now, the story of blast-furnace operation is practically a continuous one. The chemical composition of the ore, fuel and flux is constantly before the manager; the volume, pressure and temperature of blast are matters of continuous record; and the conditions at the top of the furnace are, in some cases, similarly reported to the management.

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* [Secretary's Note.—This report of Mr. Birkinbine's remarks is here printed as a substitute for the version contained in the *Bi-Monthly Bulletin* for September, 1905, p. 1151, which was published without opportunity of revision by him.—R. W. R.]

In studying the operations of a blast-furnace, all of the above are of assistance; for, otherwise, conclusions may be based on erroneous data. As an instance of this, we find that much of the irregularity in the operation of some of the larger blast-furnaces is credited to the large amount of fine ore fed into them, an amount in most cases certainly more than was charged in earlier practice. But we omit to give consideration to the fact that, owing to the method of supplying the raw material to blast-furnaces through bins, scale hopper-cars, self-dumping skips, double bells, etc., all the raw materials are more comminuted by abrasion, and by dropping from one receptacle to another. As a result, there is received at the top of the furnace not only fine ore, and more or less fine limestone, but a larger amount of finely comminuted coke, which may become incandescent, but cannot be consumed until the oxygen of the blast reaches it; and this reaction is so intense as to produce explosions similar to those which occur in dry coal-mines, grain-elevators, flour-mills, etc., where finely divided carbon meets with a spark of flame.

Mr. Johnson's paper offers an interesting field for future research; and he is to be congratulated on the manner in which he has collected the data and thanked for bringing them before the Institute, where it will invite a wide discussion.

APPENDIX.

LIST OF MEMBERS

CORRECTED TO

NOVEMBER 15, 1905.

American
Institute of Mining Engineers.

Officers, Members, Rules, Etc.

November 15, 1905.

American Institute of Mining Engineers.

(Organized in 1871, and Incorporated in 1905.)

OFFICERS.

For the year ending February, 1906.

Directors.

JAMES GAYLEY (President), R. W. RAYMOND (Secretary),
FRANK LYMAN Treasurer).

T. A. RICKARD	New York, N. Y.
CHARLES H. SNOW	New York, N. Y.
R. W. RAYMOND	New York, N. Y.

(Terms expire February, 1906.)

JAMES GAYLEY	New York, N. Y.
FRANK KLEPETKO	New York, N. Y.
FRANK LYMAN	New York, N. Y.

(Terms expire February, 1907.)

JAMES DOUGLAS	New York, N. Y.
JAMES F. KEMP	New York, N. Y.
ALBERT R. LEDOUX	New York, N. Y.

(Terms expire February, 1908.)

Council.

President of the Council.

JAMES GAYLEY.

Vice-Presidents of the Council.

GEORGE W. MAYNARD	New York, N. Y.
JULIAN KENNEDY	Pittsburg, Pa.
CHARLES D. WALCOTT	Washington, D. C.

(Terms expire February, 1906.)

WILLIAM P. BLAKE	Tucson, Ariz.
THOMAS F. COLE	Duluth, Minn.
IRVING A. STEARNS	Wilkes-Barre, Pa.

(Terms expire February, 1907.)

Councilors.

FRANK KLEPETKO	New York, N. Y.
BENJAMIN B. LAWRENCE	New York, N. Y.
HEINRICH RIES	Ithaca, N. Y.

(Terms expire February, 1906.)

F. L. GRAMMER	Baltimore, Md.
JOSEPH HARTSHORNE	Pottstown, Pa.
CHARLES H. SNOW	New York, N. Y.

(Terms expire February, 1907.)

A. A. BLOW	Washington, D. C.
FRANK LYMAN	New York, N. Y.
T. A. RICKARD	New York, N. Y.

(Terms expire February, 1908.)

Secretary of the Council.

R. W. RAYMOND	New York, N. Y.

(Term expires February, 1906.)

Blair & Rudd, New York, N. Y., Consulting Attorneys.

PAST OFFICERS.

Presidents.

*David Thomas	1871
R. W. Raymond	1872
R. W. Raymond	1873
R. W. Raymond	1874
*A. L. Holley	1875
*Abram S. Hewitt	1876
*T. Sterry Hunt	1877
*Eckley B. Coxe	1878
*Eckley B. Coxe	1879
*William P. Shinn	1880
William Metcalf	1881
*Richard P. Rothwell	1882
Robert W. Hunt	1883
James C. Bayles	1884
James C. Bayles	1885
Robert H. Richards	1886
*Thomas Egleston	1887
William B. Potter	1888
Richard Pearce	1889
*Abram S. Hewitt	1890
John Birkinbine	1891
John Birkinbine	1892
H. M. Howe	1893
John Fritz	1894
*J. D. Weeks	1895
E. G. Spilsbury	1896
*Thomas M. Drown	1897
C. Kirchhoff	1898
James Douglas	1899
James Douglas	1900
E. E. Olcott	1901
E. E. Olcott	1902
Albert R. Ledoux	1903
Albert R. Ledoux	1904

Secretaries.

*Martin Coryell	1871–1872
*Thomas M. Drown	1873–1884
R. W. Raymond	1884 ——

Treasurers.

J. Pryor Williamson	1871–1872
*Theodore D. Rand	1872–1903
Frank Lyman	1903 ——

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* Deceased.

HONORARY MEMBERS.

Prof. Richard Åkerman	Stockholm, Sweden.
Andrew Carnegie	New York, N. Y.
Prof. Hans Hoefer	Leoben, Austria.
Prof. Haton de la Goupillière	Pau, Basses, Pyrénées, France.
Prof. Henri Louis Le Chatelier	Paris, France.
M. Floris Osmond	Paris, France.
Prof. Dimitry Constantin Tschernoff	St. Petersburg, Russia.
Prof. Dr. Hermann Wedding	Berlin, Germany.

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Bell, Sir Lowthian	1904
Castillo, A. Del	1895
Contreras, Manuel Maria	1902
Daubrée, A.	1896
Drown, Thomas M.	1904
Gaetzschmann, Moritz	1895
Gruner, L.	1883
Hunt, T. Sterry	1892
Kerl, Bruno	1905
Le Conte, Joseph	1901
Lesley, J. P.	1896
Patera, Adolph	1890
Percy, John	1889
Posepny, Franz	1895
Richter, Theodor	1898
Roberts-Austen, W. C.	1902
Serlo, Albert	1898
Siemens, C. Williams	1883
Thomas, David	1882
Tunner, Peter R. von	1897

Members and Associates.

Corrected to November 15, 1905.

THOSE MARKED THUS * ARE MEMBERS; MARKED THUS † ARE ASSOCIATES. THESE SIGNS DOUBLED INDICATE LIFE MEMBERS AND ASSOCIATES RESPECTIVELY. THE FIGURES AT THE END OF THE ADDRESS INDICATE THE YEAR OF ELECTION. HEAVY-FACED TYPE SIGNIFIES HONORARY MEMBERSHIP.

*Aarons, Julian B., Mine Supt., The Boulder Deep Levels, Ltd., Boulder, Western Australia, '05
*Abadie, Emile R., Cons. and Min. Engr., 1004 James Flood Bldg., San Francisco, Cal. '76
*Abbe, Cleveland, Jr., Geol. Aid, U. S. Geological Survey, Washington, D. C. '00
*Abbott, Ai Arthur, Cerro de Pasco Mining Co., Cerro de Pasco, Peru, So. America. '95
*Abbott, Arthur V., Electrical Engr., Westinghouse, Church, Kerr & Co., 8 Bridge St., New York, N. Y. '82
*Abbott, Clarence E., Chief Min. Engr., Care Fayal Mine, Eveleth, Minn. '04
*Abbott, James W., Min. Engr., Special Agent, Rocky Mountain and Pacific Coast Division, U. S. Dept. of Agriculture, "The New Markham," Denver, Colo. '94
*Abe, Masayoshi, Prof. of Mining, Imperial University.....Kyoto, Japan. '05
†Acker, E. O'C., Supt., Treatment Dept., Bethlehem Steel Co., South Bethlehem, Pa. '86
*Adachi, Jinzoo....................No. 11 Shiba Park, Shiba-ku, Tokio, Japan. '88
*Adams, Cuyler, Mine Owner..Duluth, Minn. '05
*Adams, G. I., Geologist, Corps of Mining Engineers, Lima, Peru, So. America. '01
*Adams, Harry C., Vice-Prest., Westmoreland Coal Co., 224 So. Third St., Philadelphia, Pa. '03
*Adams, Henry.................................7 Fremont St., New London, Conn. '02
*Adams, Huntington, Min. Engr..Hotel Francia, Oaxaca, Oaxaca, Mexico. '03
*Adams, Mason T.................................747 Fifth Ave., New York, N. Y. '02
*Adams, Randolph, Min. Engr., General Mgr., Tennessee Copper Co., Copperhill, Tenn. '90
*Adams, Thomas J., Designer and Chief Draughtsman, New Jersey Zinc Co., 71 Broadway, New York, N. Y. '02
*Adams, W. Edward, Min. Engr.......................................Address wanted. '03
*Adams, Walter C., Min. Engr........................Vacas, Durango, Mexico. '99
*Adams, William H., Min. Engr. and Met..18 Broadway, New York, N. Y.. '80
*Addicks, Lawrence, Elect. Engr., De Lamar's Copper Refining Co., Chrome, N. J. '02
*Addie, Robert, Min. Engr. and Met., Kennedy & Addie, Cons. Engrs., Norfolk House, Laurence Pountney Hill, London, E. C., England. '98

*AERTSEN, GUILLIAEM, Genl. Mgr., Latrobe Steel Co.,
1200 Girard Building, Philadelphia, Pa. '88
*AGABEG, EDGAR C., Cons. Min. Engr.,
Panuria P. O. via Sitarampore, E. I. R., Bengal, India. '05
*AGNEW, FRANK VAN, Mine Assayer, Spassky Works, Akmolinsk, Siberia. '04
††AGNEW, GEORGE B.........................22 William St., New York, N. Y. '03
*AGNEW, JAMES C., Asst. Mgr., Mahoning Ore & Steel Co., Hibbing, Minn. '04
*AGNEW, WILLIAM C., Genl. Mgr., Mahoning Ore and Steel Co.,
Hibbing, Minn. '00
*AGUILAR PONCIANO, Min. Engr................Estrella, Guanajuato, Mexico. '01
*AGUILERA, PEDRO T., Cons. Engr.....................Santiago de Cuba, Cuba. '05
*AHBE, FREDERIC R., Min. Engr.........................Box 230, Ambridge, Pa. '97
*AHIER, PHILIPPE D., Mgr., The Idaho-Alamo Cons. Mines, Ltd.,
Three Forks, B. C., Canada. '04
*AHLERS, RUDOLPH O., Min. Engr., The Red Lodge,
Mitcham, Surrey, England. '99
*AHLES, ROBERT L., Prest., Basic Iron Ore Co.................Buttzville, N. J. '02
Åkerman, Prof. Richard, Director Genl. and Chief of the Swedish Board
of Trade, 34 Kungsgatan, Stockholm, Sweden.
*AKERS, WILLIAM A., Min. Engr.,
519 Guaranty Trust Bldg., El Paso, Texas. '89
*ALABASTER, RUPERT C., Met.,
28 Dawson Place, Bayswater, London, England. '05
*ALATORRE, RAFAEL F., Mine Mgr.,
Apartado 99, Pachuca, Hidaldo, Mexico. '04
*ALBERGER, LOUIS R., Mech. Engr., Prest., Alberger Condenser Co.,
95 Liberty Street, New York, N. Y. '99
*ALBERT, HERMAN H., Min. Engr................................Address wanted. '04
*ALDASORO, ANDRÉS, Min. Engr., etc., Subsecretario del Ministerio de Fomento Colonizacion é Industria, Ministerio de Fomento, Av. Balderas, No. 1026, Mexico City, Mexico. '02
*ALDRICH, TRUMAN H., Min. Engr., Coal Operator.........Birmingham, Ala. '78
*ALDRICH, TRUMAN H., JR., Min. Engr. and Coal Operator, Aldrich
Mining Co., 406 Woodward Bldg., Birmingham, Ala. '96
*ALDRICH, WILLIAM F., Prest., Coal Mining Co...................Aldrich, Ala. '81
*ALDRIDGE, WALTER H., Chief of Min. and Met. Dept.,
Canadian Pacific Ry., Trail, B. C., Canada. '89
*ALEXANDER, CURTIS, Met.,
Care Compania Metalurgica Mexicania, Apartado 132,
San Luis Potosi, Mexico. '84
*ALEXANDER, GEORGE E., Chemist and Met...2739 E. Colfax, Denver, Colo. '01
*ALEXANDER, HENRY B., Mine Mgr.. ....Kaslo, B. C., Canada. '97
*ALLAN, JOHN F., Cons. Min. Engr.,
Cia de Rio Tinto, Ltd., Calle de Valenzuela No. 4, Madrid, Spain. '90
*ALLAN, LEIGH, Min. Engr.......418 W. 2d South St., Salt Lake City, Utah. '99
**ALLAN, THOMAS A., Care Fergus Allan, Mina Mexico, El Oro,
Tultenango, Est. de Mexico, Mexico. '95
*ALLDERDICE, TAYLOR, 3d Vice-Prest., National Tube Co.,
1711 Frick Bldg., Pittsburg, Pa. '92
*ALLEN, ANSON W., Supt., Steel Dept., A. and P. Roberts Co., Pencoyd, Pa. '87
*ALLEN, JAMES, Min. Engr...............Clyde Street, Dunedin, New Zealand. '89
*ALLEN, JOHN H., Met....Knox & Allen, 82 Beaver St., New York, N. Y. '84

*ALLEN, ROBERT, Met., Care A. E. Morgan, 293 St. George's Terrace, Perth, Western Australia. '98

*ALLEN, THEOPHILUS, Mine Mgr...............1005 Bryant St., Palo Alto, Cal. '94

*ALLEN, WALTER W., Cons. Engr., Room 1307–24 Broad St., New York, N. Y. '86

*ALLISON, ROBERT, Retired Mnfr. Mining Machinery.......Port Carbon, Pa. '86

*ALMY, WILLIAM F., Min. Engr., Room 315, Trust Bldg., 60 State St., Boston, Mass. '80

*ALTHOUSE, HARRY W., Min. Engr.................................Pottsville, Pa. '02

*AMBROSIUS, CARL E., Mine Owner, Ambrosius Hermanos, Guanacevi, Durango, Mexico. '99

*AMBROSIUS, JULIUS R., Mine Operator, Apartado No. 78, Merelia, Michoacan, Mexico. '99

*AMSDEN, FRANK F., Mngr., Paxton Furnaces, Central Iron and Steel Co., Harrisburg, Pa. '87

*AMSDEN, OTTO B., Min. Engr., Supt., Clover Leaf Gold Mining Co., Roubaix, So. Dakota. '93

**AMY, ERNEST J. H., Banker, Care H. Amy & Co., 44 Wall St., New York, N. Y. '85

*ANCELLE, CHARLES E. A., Civ. Engr., Care M. Julhiet, 52 William St., New York, N. Y. '02

*ANDERSEN, CARL, Min. Engr., Genl. Supt. and Managing Engr., Nevada Keystone Mining Co., Sandy, Nev. '97

*ANDERSON, ALBERT J., Min. Engr..................702 7th St., Petaluma, Cal. '03

*ANDERSON, AXEL E., Min. Engr., Care Zeigler Coal Co..........Zeigler, Ill. '04

*ANDERSON, FRANK, Min. Engr., U. S. Deputy Mineral Survey, Utah and Nevada, 7 Masonic Bldg., Salt Lake City, Utah. '96

*ANDERSON, J. K., Civ. and Min. Engr., Asst. Engr., Pocohontas Coal and Coke Co., Bramwell, W. Va. '99

*ANDERSON, JOHN WILKINSON, Civ. and Min. Engr., Guyandot Land Association, Dunlow, West Va. '02

*ANDERSON, MARTIN L., Mine Foreman, Care Liberty Bell Gold Mining Co., Telluride, Colo. '02

*ANDERSON, ROBERT HAY, Cons. Min. Engr., 1a Independencia No. 9, Mexico City, Mexico. '95

*ANDERSON, R. WILSON, Met. Engr. and Supt., Open Hearth Furnace, Carbon Steel Co., Pittsburg, Pa. '96

*ANDERSON, WILLIAM P., Ferro-Concrete Cons. and Mining, 46 Mitchell Bldg., Cincinnati, O. '01

**ANDREW, THOMAS, Min. Engr., Mgr., Kalfontein Diamond Mines, Ltd., Pretoria, So. Africa. '94

*ANDREWES, EDWARD, Maen Offeren Slate Quarry Co., Portmadoc, N. Wales, Great Britain. '01

*ANTHONY, R. G. STANLEY, Min. Engr., Care E. V. Pierce, The Hollis Hayle, Cornwall, England. '00

**ANTZ, EUGENE, Met..Cuprum, Idaho. '99

*APPLEBY, WILLIAM R., Dean of the Minnesota School of Mines and Prof. of Met., School of Mines Bldg., State University, Minneapolis, Minn. '90

*ARCHBALD, JAMES, Cons. Engr...............424 Jefferson Ave., Scranton, Pa. '87

*ARCHIBALD, CHARLES........................32 Inglis St., Halifax, Nova Scotia. '86

*ARCHIBALD, MUNROE.........................P. O. Box 25, Truro, Nova Scotia. '98

*ARENTS, ALBERT..............................561 Railroad Avenue, Alameda, Cal. '82

**ARGALL, JOSEPH, Min. Engr., Iron Mast Mine, Kamloops, B. C., Canada. '03

*ARGALL, PHILIP, Min. Engr. and Met., 728–732 Majestic Bldg., Denver, Colo. '92

*ARLETT, GEORGE H., Min. Engr. and Met., Apartado 159, Chihuahua, Mexico. '00

*ARMAS, MILTIADES TH., Cons. Min. Engr., Gen. Mgr., La Paz Mining Co., Cassilla No. 8, La Paz, Bolivia, So. America. '96

**ARMSTEAD, HENRY H., JR., Min. Engr., 21 W. 31st St., New York, N. Y. '00

*ARMSTRONG, HARLEY J., Assayer and Chem., Care Bourne Gold Mining Co., Bourne, Ore. '03

*ARMSTRONG, JOHN O., Cons. Engr., Genl. Mgr., The Crowl Creek Mining Co., Shuttleton, New South Wales, Australia. '94

*ARMSTRONG, THOMAS, Mineral Draughtsman, Surveyor General's Office, Phœnix, Ariz. '95

*ARNAUD, GEORGES..............................55 rue Runnequin, Paris, France. '91

*ARNBERG, C. T., Supt., Steel Dept., Wheeling Steel and Iron Co., Wheeling, W. Va. '81

*ARNOLD, LEO F., Min. Engr....................1426 Montana St., Chicago, Ill. '05

*AROZARENA, RAFAEL M. DE, 2da Calle de las Estaciones Esquina del Encino, Mexico City, Mexico. '98

*ARTHUR, EDWARD P., JR..............Bi-Metallic Bank, Cripple Creek, Colo. '97

*ASHLEY, GEORGE H.............U. S. Geological Survey, Washington, D. C. '99

*ASHLEY, H. H., Prest......................Parrish Coal Co., Wilkes-Barre, Pa. '94

*ASHMORE, ERNEST P., Cons. Min. and Met. Engr., Care Genl. Mgr., Porsa Copper Mines, Porsa, Finmarkin (near Hammerfest), Norway. '00

**ASHMORE, G. PERCY, Cons. Min. and Met. Engr., 13 Calle Audienca, Caceres, Spain. '97

**ASHTON, FRANK, Min. Engr., Consuelo Mining and Milling Co., Dolores, Chihuahua, Mexico. '00

*ASTLEY, JOHN W., Le Roi Mining Co., Ltd.........Rossland, B. C., Canada. '91

*ATHA, BENJAMIN, Prest., Benj. Atha Co. (Crucible Steel Co. of America), Newark, N. J. '84

**ATHERTON, T. W. T., Chief Min. Engr., Ivory Coast Mining Corporation, 29 Broad St. Ave., London, E. C., England. '92

*ATKINS, WILLIAM, Treas., Kingwood Coal Co., 1208 North American Bldg., Philadelphia, Pa. '81

*ATKINSON, LOUIS W., Min. Engr........ Supt. Marmet Co., Marmet, W. Va. '94

**ATTWOOD, G., Cons. Min. and Civ. Engr., 13 Sise Lane, Queen Victoria St., London, E. C., England. '75

*ATWATER, CHRISTOPHER G., Supt., Coke Ovens...........Chadd's Ford, Pa. '03

*ATWATER, RICHARD M., JR., Cons. Min. Engr., Gold Block, Helena, Mont. '97

*AUBURY, LEWIS E., State Mineralogist of California, Ferry Bldg., San Francisco, Cal. '00

*AUER, CHARLES L., Assayer and Chem., 3407 Burner Ave., Avondale, Cincinnati, Ohio. '04

*AUSTIN, ALBERT M., Mgr., San Francisco Mine....Llano, Sonora, Mexico. '05

*AUSTIN, J. B., Min. Engr...Santa Barbara, Cal. '83

**AUSTIN, KENNETH, Cons. Engr., 36 St. James Mansions, West Hampstead, London, N. W., England. '97

*AUSTIN, LEONARD S, Professor of Metallurgy, Michigan College of Mines, Houghton, Mich. '94

*Austin, Peter T., Chem. Expert..............89 Pine St., New York, N. Y. '05
**Austin, T. S., Genl. Supt., Southern Dept., American Smelting & Refining Co., Aguascalientes, Mexico. '83
*Austin, W. Lawrence...............167 Columbia Heights, Brooklyn, N. Y. '82
†Avery, Colby M., Briquetting Engr., Chisholm, Boyd & White Co., 57th and Wallace Sts., Chicago, Ills. '03
*Avery, John, Mine Operator, Tongio, West Gippsland, Victoria, Australia. '03
*Ayers, Frederic G...........16 Weymouth St., Adelaide, South Australia. '98
†Ayres, Emma L. C..Bound Brook, N. J. '03
*Ayres, W. S., Min. and Mech. Engr., C. P. R. R. Mining Dept., Banff, Alberta, Canada. '73
*Ayton, Ernest F., Gen. Mgr., The Parral Mines, Ltd., Santa Barbara, Chihuahua, Mexico. '95

*Babbitt, Thomas D., Min. Engr....................................Address wanted. '99
*Bache, Franklin, Min. Engr., Prest., McAlester Coal Co., Fort Smith, Ark., and 505 Land Title Bldg., Philadelphia, Pa. '91
*Bachman, David I..Keystone, W. Va. '92
*Bachman, F. E., Genl. Mgr., Northern Iron Co............Port Henry, N. Y. '80
*Bacon, Don H., Chairman and Prest., Tennessee Coal, Iron & R. R. Co., 100 Broadway, New York, N. Y. '86
*Bacorn, Frederick W., Atty. at Law, Prest., Cable Lease Mining Co., etc., Butte, Mont. '03
*Badger, Harry S., Met. Engr...Bridgewater, Limenburg Co., Nova Scotia. '02
*Badlam, Stephen, Asst. Supt., Merchant Mill Dept., Pennsylvania Steel Co., Steelton, Pa. '99
*Baer, George F., Prest., Phila. & Reading Terminal Railway Co., Reading Terminal, Philadelphia, Pa. '92
**Baggaley, Ralph, Manufacturer and Miner, Prest., Puritan Coke Co., etc., 401 Tradesmen Bldg., Pittsburg, Pa. '00
*Bagge, Nils O...60 Wall St., New York, N. Y. '02
*Bailey, B. N., Civ. Engr..................."The Gladstone," Philadelphia, Pa. '00
*Bailey, Charles, Treas., Reliance Tube Co., Ltd., Arrott Bldg., Pittsburg, Pa '86
*Bailey, Edward, Prest., Central Iron & Steel Co............Harrisburg, Pa. '02
*Bailey, Edward Trenholm, Min. Engr., Care F. W. Bailey, 1 Burlington Place, Carlisle, England. '02
*Bailey, J. Trowbridge, Min. Engr., Engineering Co. of America, 74 Broadway, New York, N. Y. '02
**Bailey, James B., Genl. Mgr. and Treas., Central Iron and Steel Co., Harrisburg, Pa. '00
†Bailey, Marc.......................1000 South Highland Ave., Chanute, Kan. '04
*Bailey, Melbourne, Genl. Mgr., Cariboo Cons. Co., Stanley, B. C., Canada. '05
*Baillie, Frank S., Vice-Prest. and Genl. Mgr., Columbia Gold Mining Co., Columbia Mine, Sumpter, Ore. '03
*Bain, H. Foster, Geologist, Care State Geological Survey, Champaign, Ill. '97
**Bain, Hugh A...Riverside, Cal. '00
*Baird, Dudley, Met..Copperopolis, Cal. '02
*Baird, Henry J. B., Smelter Supt., The Canadian Copper Co., Copper Cliff, Ontario, Canada. '03
*Baker, C. O., Prest., Baker & Co., Inc., 120 Liberty Street, New York, N. Y. '95

*BAKER, DAVID, Cons. Met. Engr., Real Estate Trust Bldg.,
Philadelphia, Pa. '86
*BAKER, FREDERICK R., Min. Engr.........Republic Coal Co., Athens, Ohio. '94
*BAKER, THOMAS T...............................414 West Quartz St., Butte, Mont. '87
*BALDWIN, JAMES M., Min. Engr.........P. O. Box 825, Deadwood, So. Dak. '93
*BALFOUR, JOHN F., Min. Engr., 17 Rosefield Ave.,
Portebello, Edinburgh, Scotland. '04
*BALTA, JOSÉ., Min. Engr., Director de Fomento, etc.,
Lima, Peru, So. America. '02
*BAMBERGER, SIDNEY M................161 South Main St., Salt Lake City, Utah. '03
*BANCROFT, GEORGE J., Min. Engr.......622 Exchange Block, Denver, Colo. '98
*BANKS, E. GRIPPER, Met., Waihi Gold Mining Co., Ltd.,
Waihi, Auckland, New Zealand. '00
*BANKS, JOHN H., Min. Engr. and Chem., Ricketts & Banks,
104 John Street, New York, N. Y. '83
*BANKS, NOBLE C., Min. and Met. Engr., 1102 Farmers' Bank Bldg.,
Pittsburg, Pa. '97
**BANON, HENRY C., Min. Engr....P. O. Duff, Dunbar, Kulu, Punjab, India. '90
**BARBER, GEORGE MARRIOT, Min. and Met. Engr., Home Bush,
Waldeck Ave., Bedford, England. '02
*BARBER, JOHN C., Mine Supt..................................Ketchikan, Alaska. '05
†BARBER, WILLIAM B., Geol. Min. Engr., 508 California St.,
San Francisco, Cal. '01
*BARBOUR, PERCY E., Engr.............................66 State St., Boston, Mass. '03
*BARBOUR, PERCY P., Min. Engr. and Surveyor.........Idaho Springs, Colo. '04
*BARBOUR, THOMAS J., Min. and Mech. Engr.,
Risdon Iron Works, San Francisco, Cal. '97
*BARCLAY, THOMAS H.............................Bookwalter, Pawnee Co., Neb. '00
*BARD, DARSIE C., Min. Engr.......................................Butte, Mont. '05
*BARDWELL, ALONZO F., Min. Engr., Assayer and Chem.,
318 Cooper Ave., Aspen, Colo. '89
*BARKER, HENRY A., Chem................St. John's Manse, Leven, Scotland. '02
*BARKER, SAMUEL, JR., Civ. and Min. Engr., Pennington & Barker,
Butte, Mont. '00
*BARKSDALE, H. M.....................Repauno Chemical Co., Wilmington, Del. '94
*BARNADO, WILLIAM S. E., Min. Engr., St. Leonard's Lodge, Surbiton,
Surrey, England. '03
*BARNETT, MAURICE......Electric Boat Co., 100 Broadway, New York, N. Y. '93
**BARNETT, WILLIAM J., Cons. Min. Engr.,
Winchester House, Old Broad St., London, E. C., England. '02
*BARNEY, MONTAGU T., Min. Engr., Aukobra Development Co.,
13 Austin Friars, London, E. C., England. '01
*BARNHART, G. H., Min. Engr., Genl. Mgr., The Ymir Gold Mines, Ltd.,
Ymir, B. C., Canada. '93
*BARRELL, ROBERT W., Cons. Min. Engr. and Met., Asst. Mgr.,
St. Louis Sampling & Testing Works, 1225 Spruce St., St. Louis, Mo. '99
*BARREN, HENRY A........................346 Amesbury Ave., Cleveland, Ohio. '02
*BARRINGER, DANIEL M., Min. Engr. and Geol., 460 Bullitt Building,
Philadelphia, Pa. '90
*BARRON, GEORGE D., Prest. and Genl. Mgr., The Tezuitlan Copper Co.,
Beaver Bldg., 82 Beaver St., New York, N. Y. '01
*BARROWS, WALTER A., JR., Genl. Mgr. Blast Furnaces,
Shenango Furnace Co., Sharpsville, Pa. '90

*BARTLETT, JAMES H....Man. Dir., American Assn., Inc., Middlesboro, Ky. '85

*BARTOL, GEORGE, Genl. Mgr........The Otis Steel Co., Ltd., Cleveland, Ohio. '79

*BASSETT, THOMAS B., Min. and Met. Engr., Mgr., Tarasca Gold Mining Co., Torres, Sonora, Mexico. '04

*BASSETT, WILLIAM H., Chem........Coe Brass Mnfg. Co., Torrington, Conn. '92

*BATCHELDER, CHESTER S., Assayer and Chemist.............Spokane, Wash. '00

*BATCHELDER, JOSEPH F...........323 Chamber of Commerce, Portland, Ore. '00

*BATCHELLER, HENRY R., Cons. Min. Engr.....Box 21, Washington, N. H. '95

*BATCHELLER, JAMES H., Min. Engr., Care H. R. Batcheller, Box 21, Washington, N. H. '00

*BATCHELOR, WILLIAM T., Civ. and Min. Engr., Mt. Lyell Mining and Railway Co., Ltd., Gormanston, West Coast, Tasmania. '02

*BATESON, CHAS. E. W., Min. Engr. and Chem., Care The Josephine Mills, Cedartown, Ga. '01

*BATZ, BARON RENÉ DE., Cons. Engr., etc., 36 Rue de Tocqueville, Paris, France. '95

*BAUMANN, ALBERT P., Min. Engr........228 East 52d St., New York, N. Y. '99

*BAUMGARTEN, KARL, Assayer, Cerro Prelto Mine, Magdalena, Sonora, Mexico. '05

*BAXTER, FRANCIS K., Min. Engr. and Chem., Supt. of Mines, Great Western Gold Co., Ingot, Cal. '04

*BAYLES, FREDERICK P., Min. Engr., Fuel Expert, American Smelting & Refining Co., Room 514, Boston Bldg., Denver, Colo. '97

**BAYLISS, RAWLINSON T., Min. Engr., Chairman, Exploration Co., Ltd., 11 Cornhill, London, E. C., England. '89

*BEAL, LATHAM O..Dunedin, New Zealand. '98

*BEALE, ADDISON H., Supt., Open Hearth Furnaces, Care Eastern Steel Co., Pottsville, Pa. '01

**BEALS, WILLIAM, JR., Min. Engr., Geol......50 Congress St., Boston, Mass. '97

*BEAN, IRVING M., Prest., Northwestern Iron Co., Pabst Building, Milwaukee, Wis. '92

*BEARDSLEY, GEORGE F., Met....................Copper Cliff, Ontario, Canada. '90

*BEATTY, A. CHESTER, Min. Engr., Asst. Genl. Mgr. and Cons. Engr., Guggenheim Exploration Co., 531 Majestic Bldg., Denver, Colo. '96

*BECK, EDWIN L., Assayer, Care Kendall Gold Mining Co...Kendall, Mont. '04

*BECKER, GEORGE F., Geol........U. S. Geological Survey, Washington, D. C. '93

*BECKER, THEODORE, Assayer, Care Stratton's Independence, Ltd., Victor, Col. '01

*BECKETT, JAMES A., Genl. Supt., Walter A. Wood Mowing and Reaping Co., Hoosick Falls, N. Y. '97

*BEELER, HENRY C., State Geol. of Wyoming..................Cheyenne, Wyo. '04

*BEHR, HANS C., Cons. Mech. Engr., Consolidated Gold Fields of So. Africa, Ltd., P. O. Box 1167, Johannesburg, Transvaal, So. Africa. '00

*BEL, J. MARC, Cons. Min. Engr....73 Boulevard St. Michel, Paris, France. '84

*BELDEN, SANFORD B., Mgr., The Jeffrey Manufacturing Co., Farmers' Bank Bldg., Pittsburg, Pa. '01

*BELIN, HENRY, JR., Powder Mnfr...............Connell Building, Scranton, Pa. '87

*BELL, ALAN D., Min. Engr., St. Joseph Lead Co...........Bonne Terre, Mo. '95

**BELL, CHARLES LOWTHIAN, Iron Master, Bell Bros., Ltd., Middlesborough, England. '97

†BELL, FRANK R., Min. Engr. and Chem., Cockerill Zinc Co., Altoona, Kansas. '03

*Bell, James Mackintosh, New Zealand Official Geologist, Wellington, New Zealand. '02
**Bell, Jno. W., Care Beccara, Nesbitt & Co., Irique, Chihuahua, Mexico. '99
*Bell, Robert, State Inspector of Mines............................Boise, Idaho. '04
*Bell, Dr. Robert.......Dir. Geological Survey of Canada, Ottawa, Canada. '85
Bell, Stanislaus, Charles N., Min. Engr., Mgr., The New Brothers Home Tin Mining Co., Derby, Tasmania. '05
*Bellam, Henry Lynch, Assayer and Chem...................Leetville, Nev. '96
*Bellinger, Herman C., Met.............................Crofton, B. C., Canada. '91
*Bellinger, H. P., Solvay Process Co., 1902 W. Genesee St., Syracuse, N. Y. '89
*Belshaw, Charles M., Mine Owner........Antioch, Contra Costa Co., Cal. '99
*Bement, A., Min. Engr...........................215 Dearborn St., Chicago, Ill. '03
*Benedict, William de L., Cons. Min. Engr..43 Cedar St., New York, N. Y. '83
*Benjamin, Edward H., Min. Engr. and Secy., California Miners' Ass'n, 331 Pine St., San Francisco, Cal. '99
*Bennet, T. A..............................Casilla 114, Lima, Peru, So. America. '90
†Bennett, Russell M., Iron and Mineral Lands, 604 New York Life Bldg., Minneapolis, Minn. '95
*Benneville, James S. de, Anal. Chem..... Post Office Yokohoma, Japan. '97
*Benson, Alexander, Cons. and Min. Engr., Room 34, Broad Street House, New Broad St., London, E. C., England. '90
*Bensusan, E. V., Min. Engr., The Abbontiakoon Block 1, Ltd., Tarkwa, Gold Coast Colony, West Africa. '92
*Bent, Felton, Prest., Solid Steel Casting Co......................Chester, Pa. '02
*Bentley, Robert, Secy. and Genl. Mgr., Ohio Iron and Steel Co., Lowellville, Ohio. '84
*Benton, C. W., Min. and Met. Engr............................Arlington, N. J. '97
*Berg, P. T., Mech. Engr..............No. 1 Strandvägen, Stockholm, Sweden. '90
*Bermingham, Jno., Jr., Supt., California Powder Works....Hercules, Cal. '02
*Berray, Niles S., Supt., The United Globe Mines.............. ..Globe, Ariz. '99
**Berry, J. F., Con. Mech. Engr., East Rand Proprietary Mines, Ltd., East Rand, Transvaal, So. Africa. '93
*Bertolet, Alfred S.........................10618 Torrence Ave., Chicago, Ill. '75
*Bettendorf, Charles, Mine Owner, Luxembourg, Gare, Grand Duchy of Luxembourg, Germany. '03
*Betts, Anson G., Chem. and Met..................Betts Laboratory, Troy, N. Y. '01
*Beyer, Samuel W., Prof. of Geology and Mining Engineering, Iowa State College, Ames, Iowa. '98
*Bible, Joseph W., Mine Mgr. and Engr.............Hanover, New Mexico. '05
*Biddle, William F..........................209 S. Third St., Philadelphia, Pa. '81
*Biesel, Charles W., Min. Engr., The St. Eugene Consolidated Mining Co., Ltd., Moyie, B. C., Canada. '03
†Bigelow, A. S., Prest. of Mining and other Companies, P. O. Box 5104, Boston, Mass. '88
*Bigelow, David E...................Box 120, Kalgoorlie, Western Australia. '01
*Bigler, S. Haldeman, Chem., Central Iron and Steel Co., Harrisburg, Pa. '02
*Bildt, Carl W., Met. Engr. with *Jernkontoret*, Vasagatan 8, Stockholm, Sweden. '86
*Bilharz, Oscar M., Min. Engr., Supt., Doe Run Lead Co., etc., Flat River, Mo. '92
*Billin, Charles E., Mfgr. Machinery, American Engineering Works, Chicago, Ill. '75

*Billings, G. H., Met. Engr.................393 Dorchester Ave., Boston, Mass. '77
*Bird, Arthur H. S...............505 E. 1st South St., Salt Lake City, Utah. '97
*Bird, Robert M., Min. Engr., Messrs. S. Pearson & Son, Ltd.,
10 Victoria St., Westminster, London, E. C., England. '97
*Bird, Robert Montgomery, Supt., Treatment Department, South
Bethlehem Steel Co., 433 Broadhead Ave., South Bethlehem, Pa. '05
*Birkinbine, John, Cons. Engr....Odd Fellows' Temple, Philadelphia, Pa. '75
*Bishop, Roy N., Min. Engr.................Greenback Mine, Greenback, Ore. '02
*Bishop, Walter B., Assayer...... ....Grand Forks, B. C., Canada. '04
*Black, Robert S., Min. Engr.,
529 Collins St., Melbourne, Victoria, Australia. '98
*Blackstone, Richard, Chief Engr., Homestake Mining Co..Lead, So. Dak. '90
*Blackwell, Francis O., Cons. Engr.........49 Wall St., New York, N. Y. '92
*Blair, Andrew A., Anal. Chem., Booth, Garrett & Blair,
406 Locust St., Philadelphia, Pa. '75
*Blake, Edwin T., Supt., Oakland Paving Co.,
Central Bank Bldg., Oakland, Cal. '03
†Blake, C. G., Coal and Coke...First National Bank Bldg., Cincinnati, Ohio. '86
**Blake, Francis H., Min. Engr...............43 Cedar St., New York, N. Y. '84
*Blake, Prof. William P., Dir., Arizona School of Mines, Territorial
Geologist, Tucson, Ariz. (Summer address, June to Sept., Mill Rock,
New Haven, Conn.) '71
*Blakemore, George H., Min. Mgr., Met. and Cons. Engr., The Electrolytic Wks., Great Cobar Copper Mining Syndicate, Leithgow,
New South Wales, Australia. '97
*Blakeslee, Frank A...................1320 Montgall Ave., Kansas City, Mo. '97
*Blandy, S. H. B., Min. Engr., Genl. Mgr., Cyphergat Coal Mining Co.,
Cyphergat, Cape Colony, So. Africa. '02
*Blatchford, John, Supt. of Mines, Golden Reward Consolidated Gold
Mining and Milling Co., Terry, So. Dak. '97
*Blauvelt, Harrington, Min. Engr. and Met., Supt., Cash Mine Co.,
Prescott, Ariz. '89
*Blauvelt, William H...............1917 West Genesee St., Syracuse, N. Y. '87
*Bliss, Collins P., Prof. of Mech. Engineering, New York University,
University Heights, New York, N. Y. '97
*Block, H. W. C....................................1804 Warren St., St. Louis, Mo. '86
*Bloomfield, Alfred L., Met., Salisbury, Uralla,
New South Wales, Australia. '05
*Blood, George Deroy, Min. Engr....134 First St., Salt Lake City, Utah. '93
*Blow, A. A., Cons. Engr.....................The Portland, Washington, D. C. '82
**Blow, John J., Min. Engr.........................Nacoochee, White Co., Ga. '04
*Blue, John, Supt., Eustis Mining Co...................Eustis, Quebec, Canada. '88
*Blumenkranz, Moses, Min. Engr., 121 San Francisco St., El Paso, Texas. '04
*Bodfish, Frederick V..Victor, Colo. '01
†Bodwell, Ernest V., Barrister at Law...............Victoria, B. C., Canada. '00
*Boehmer, Max., Min. Engr..................42 Jacobson Bldg., Denver, Colo. '84
*Boggs, William R., Jr., Chem. and Met., Mgr., Compania Metalurgica Argentina, Villa Mercedes, Prov. San Luis, Argentine Republic, So. America. '82
*Bohn, Charles A., Min. Engr., Genl. Mgr., Eucinillas Mines, Ltd.,
Santa Rosalia, Chihuahua, Mexico. '93
*Bolles, J. H..........................Hagerman Bldg., Colorado Springs, Colo. '92
*Bolles, Myrick N., Chem., Metallurgical Dept., Columbia University,
New York, N. Y. '03

*Bolton, Charles C..................Care M. A. Hanna & Co., Cleveland, Ohio. '95
*Bond, Josiah, Genl. Mgr., American Copper Co...........Somerville, N. J. '03
*Bonestell, H. S...Gaston, Cal. '99
*Bonillas, Ygnacio, Min. and Civ. Engr.,
P. O. Box 154, Nogales, Sonora, Mexico. '91
*Bonwick, Edwin Walter, Care Bewick, Moreing & Co.,
20 Copthall Ave., London, E. C., England. '02
*Bonzano, Adolphus, Civ. and Mech. Engr., Prest., Bonzano Rail Joint Co.,
22 So. Fifteenth St., Philadelphia, Pa. '86
**Booraem, Robert E., Min. Engr.........19 W. 31st St., New York, N. Y. '87
*Boorne, William H., 18 Grosvenor Mansions,
82 Victoria St., London, S. W., England. '99
*Booth, Franklin, Min. Engr., Vice-Prest., Levi Booth & Sons, Inc.,
Box 594, Station C, Los Angeles, Cal. '92
*Borchers, Dr. Wilhelm, Prof. of Met., Rekton of the Royal College of
Technology, Aachen, Germany. '01
*Bordeaux, Albert F. J., Min. Engr.,
Picdimulere, la Villa (Novara), Italy. '04
*Borden, Gideon S., Civ. and Min. Engr., Collier Colliery Co.,
Glen Jean, W. Va. '02
*Borgner, Cyrus, Mfr., Fire Brick, Clay Retorts and Cement,
Cyrus Borgner Co., 23d above Race St., Philadelphia, Pa. '02
*Borrow, Frank K., Min. Engr..38 Nevern St., London, S. W., England. '01
*Bosch, Anton, Met. Engr., Care Herbert Haas, 218 California St.,
San Francisco. Cal. '02
*Bosco, Francis W., Chem., Assayer...1932 So. Sherman Ave., Denver, Colo. '02
*Bosqui, Francis L., Met. Engr.......531 California St., San Francisco, Cal. '97
*Bostwick, William A., Met. Engr.......Carnegie Steel Co., Pittsburg, Pa. '05
*Bottomley, H., Deputy Inspector of Mines,
Rand Club, Johannesburg, Transvaal, So. Africa. '02
*Botsford, Robert S., Min. Engr., Care Thomas Meadows & Co.,
35 Milk St., London, E. C., England. '05
*Bouchelle, John F., Min. Engr...........80 Murray St., New York, N. Y. '05
**Boucher, Arthur S., Min. and Civ. Engr., Sharpcliffe Hall, Ipstones,
Staffordshire, England. '94
*Boutwell, John M., Min. Geol. U. S. Geological Survey,
Washington, D. C. '04
*Bowden, James E...............................423 Elizabeth St., Denver, Colo. '02
*Bowden, Josiah J., Mill Supt., Penobscot Mining Co....Marysville, Mont. '01
*Bowen, Herbert P., Min. Engr., Assayer and Mine Surveyor,
Douglas, Ariz. '04
*Bower, Charles P., Civ. Engr...................520 Walnut St., Reading, Pa. '94
*Bowie, Alexander, Genl. Mgr., Caledonian Coal Co., Gallup, New Mexico. '90
†Bowles, Henry Thornton.................. ...35 Wall St., New York, N. Y. '02
*Bowron, Charles E., Min. Engr., Ramsay & Bowron....Birmingham, Ala. '93
*Bowron, James.......................1401 So. Twentieth St., Birmingham, Ala. '78
*Bowron, William M., Cons. Engr..........................Chattanooga, Tenn. '05
*Boyd, Augustus W., Min. Engr., Supt., American Consolidated Gold
Mining Co., Ltd., Elk City, Idaho Co., Idaho. '01
†Boyd, Frederick J., Waters Pierce Oil Co., 2^A de San francisco Num. 11,
Apartado 34, Bis, Mexico City, Mexico. '02
*Boyd, John Y., Prest., Tyrone Iron Co.....222 Market St., Harrisburg, Pa. '86

*Boyd, Thornton M., Assayer,
Tasmania Reduction Works, Beaconsfield, Tasmania. '01
*Boyd, William Sprott, Min. Engr...............Instructed to hold all mail. '02
*Boyle, Emmet D., Mine Supt., North Rapidan Gold and Silver Mining Co.,
Dayton, Nev. '03
*Boyle, James L., Mining and Tank Manufacturer,
607 Clarondelet St., Los Angeles, Cal. '05
*Boynton, A. J., Asst. Supt., Blast Furnaces, National Tube Co.,
218 East 5th St., Elyria, Ohio. '04
†Boynton, Henry C., Instructor in Metallurgy,
23 Ellsworth Ave., Cambridge, Mass. '01
*Boyt, John, Asst. Supt., Blast Furnaces of Maryland Steel Co.,
Sparrows Point, Maryland. '02
*Braden, William, Min. Engr., Care Braden Copper Co.,
Graneros, Chili, South America. '98
*Bradford, Robert H., Prof. of Metallurgy, Center Ward,
Salt Lake City, Utah. '02
**Bradford, Seymour K., Civ. and Min. Engr..............Tonopah, Nevada. '02
*Bradford, Wager, Mine Mgr., Langlaagte Deep, Ltd.,
Box 1056, Johannesburg, Transvaal, So. Africa. '02
*Bradley, Durbin H., Jr., Min. Engr..........Parral, Chihuahua, Mexico. '03
**Bradley, Frederic W., Min. Engr., Prest., Bunker Hill and Sullivan
M. & C. Co., etc., Crocker Bldg., San Francisco, Cal. '91
*Bradley, George L.........1503 Twenty-first St., N. W., Washington, D. C.
(Summer address, Pomfret Centre, Conn.) '74
*Bradley, John C., Genl. Supt., Pratt & Letchworth Co.,
189 Tonawanda St., Buffalo, N. Y. '99
**Bradley, Philip R., Min. Engr.,
Georgetown, British Guiana, South America. '02
*Bradley, Richard J. H., Min. Engr.,
Care Bradley, Ford & Co., 42 Broadway, New York, N. Y. '02
*Bradley, Walter Wadsworth, Min. Engr..............................Bodie, Cal. '02
*Bradshaw, Frederick, Mine Mgr., Santo Domingo Silver Mining Co.,
Batopilas, Chihuahua, Mexico. '02
*Brady, James, Min. Engr............Golden, East Kootenay, B. C., Canada. '96
*Brady, Leon H., Min. Engr., Care American Smelting & Refining Co.,
Asientos, Aguascalientes, Mexico. '05
**Brandes, Juan Felix, Cons. Min. Engr.....1160 Race St., Denver, Colo. '02
*Branner, John C., Prof. of Geology and Vice-Prest.,
Leland Stanford University, Stanford University, Cal. '84
*Braschi, Victor M., Engr. and Contractor, Calle de Cadena No. 2,
Apartado 830, Mexico City, Mexico. '91
*Brassert, H. A., Supt., Blast Furnaces, Illinois Steel Co.,
South Chicago, Ill. '99
*Breakell, Thomas, Min. Engr.........Brassington near Derby, Tasmania. '05
*Breen, James..Spokane, Wash. '87
*Breisch, Ernest E., Min. Engr...........................Moundsville, W. Va. '96
*Breitung, Edward N., Mine Mgr., Savings Bank Bldg..Marquette, Mich. '05
*Brendel, Robert, Genl. Supt. of Mines, M. Guggenheim Sons, of New York,
2ª Independencia No. 1, Aguascalientes, Mexico. '98
*Brennon, John C., Min. Engr., Vice-Prest. and Genl. Mgr., Ajuchitlan
Mining & Milling Co. of S. A., Ahorcado, Queretaro, Mexico. '01

**Bret, Jean le................................57 Avenue D'Antin, Paris, France. '98

*Bretherton, George K., German-American Mining Co......Vivian, Ariz. '00

**Bretherton, S. E...Ingot, Cal. '89

*Bretherton, Wallace B., Chem., Care Great Western Gold Co.,
Ingot, Cal. '05

*Bretherton, Walter L., Genl. Mgr., Clark Coal Co.,
Clarkville, New Mexico. '87

*Brett, Alfred J., Surveyor, Athenaeum Club,
Johannesburg, Transvaal, So. Africa. '02

**Brewer, Arthur K., Met., Supt., Cia. Minera Fundidora y Afinadora
"Monterey," Monterey, Mexico. '97

†Brewer, Robert Edward, Student........320 Marlboro St., Boston, Mass. '02

*Brewer, William M.................P. O. Box 571, Victoria, B. C., Canada. '93

*Bridge, Samuel D., Assayer and Chem....Apartado 50, Monterey, Mexico. '01

*Briggs, Roswell E., Civil Engr.......Calle Gante 8, Mexico City, Mexico. '01

*Briggs, William A. J., Assayer and Surveyor............Zeehan, Tasmania. '03

*Brigstocke, Robert W., Mine Supt., Drummond Mines, Ltd.,
Haileybury, Ontario, Canada. '05

*Brill, Joseph W., Mine Mgr.......Apartado 47, Oaxaca, Oaxaca, Mexico. '05

**Brinell, Johan A., Chief Engr.........Jernkontoret, Stockholm, Sweden. '98

*Brinker, Arthur C., Min. Engr., Care Camp Bird, Ltd......Ouray, Colo. '01

**Brinsmade, Robert B., Constructing Engr., Rossi Iron Ore Co.,
Spragueville, N. Y. '99

**Britt, Richard H., Mine Mgr., Poorman Gold Mining, Ltd.,
Silver City, Idaho. '98

**Britten, Thomas J., Wolhuter Gold Mining Co.,
Johannesburg, Transvaal, So. Africa. '95

*Broad, Wallace, Geol. and Min. Engr., Care John Birch & Co., Ltd.,
3 London Wall Bldgs., London, E. C., England. '01

*Brock, Arthur...Lebanon, Pa. '87

*Brock, Charles, Prest., Boonton Iron and Steel Co............Boonton, N. J. '81

*Brock, Reginald W., Geol. School of Mining..Kingston, Ontario, Canada. '04

*Brockunier, Samuel H., Min. Engr., Secy., Kaaterskill Paving Brick Co.,
Catskill, N. Y. '00

**Brodie, Walter M., Min. Engr. and Met................Chihuahua, Mexico. '72

*Bromly, Alfred H., Min. Engr., Care A. J. Kappele, 537 Haskins St.,
Vancouver, B. C., Canada. '97

*Brook, Henry E. C., Mine Mgr., Great Lucknow Consols, Ltd.,
Cadia, via Orange, New South Wales, Australia. '04

*Brooke, Robert E., Treas., E. & G. Brooke Iron Co.........Birdsboro, Pa. '02

**Brooke, Henry, Supt., Ephraim Creek Coal & Coke Co...Thayer, W. Va. '03

**Brooks, Alfred H., Geol., U. S. Geological Survey,
In charge of Alaskan Mineral Resources, Washington, D. C. '00

*Brooks, John McM., Jr., Min. Engr..................................Rolla, Mo. '04

*Brooks, Raymond, Care Doane Mine............................Rambler, Wyo. '05

*Brophy, James, Mine Operator, Care McDowell & Co....Kimball, W. Va. '01

*Brown, Alden H., Mine Supt., Wano Mining and Development Co.,
Jamestown, Colo. '03

*Brown, Alexander E., Vice-Prest. and Genl. Mgr.,
Brown Hoisting Machinery Co., Cleveland, Ohio. '75

**Brown, Amos P., Prof. of Geology and Mineralogy,
University of Pennsylvania, Philadelphia, Pa. '88

**BROWN, ARCHIBALD T., Cons. Min. Engr., 372 Flin
Melbourne, V ia, Australia. '91

*BROWN, ARTHUR H., Met. and Chem., Daly Reduction Co.,
Hedley, B. C., Canada. '02

*BROWN, AUSTIN H., Min. Engr. and Genl. Mgr., Trinity Copper Co., etc.,
Kennett, Shasta Co., Cal. '92

*BROWN, CONY T., Mgr., Mine Development Association,
Socorro, New Mexico. '00

†BROWN, DAVENPORT, Min. Engr..................144 Oliver St., Boston, Mass. '02

*BROWN, DONALD C., Asst. Genl. Mgr., Compania Metalurgica Mexicana,
Apartado 132, San Luis Potosi, Mexico. '01

*BROWN, DOUGLAS P., Min. Engr.,
Whitehouse, Northallerton, Yorkshire, England. '03

*BROWN, EDWARD L., Treas. and Supt., Chicago Drop Forge and Foundry Co.,
Kensington, Ill. '81

*BROWN, E. PERCY, Min. Engr..........................Bridgewater, Nova Scotia. '98

*BROWN, ELWIN F.............Genl. Mgr., Pewabic Co., Iron Mountain, Mich. '91

†BROWN, FAYETTE, Prest. of Manufacturing Cos.,
Perry-Payne Bldg., Cleveland, Ohio. '75

*BROWN, FREDERICK C., Genl. Mgr., Komata Reefs Gold Mining Co., Ltd.,
Komata, via Paeroa, Auckland, New Zealand. '00

*BROWN, HARVEY H., Mfr., Harvey H. Brown & Co., 301 Perry-Payne
Bldg., Cleveland, Ohio. '76

*BROWN, HORACE F., Min. and Mech. Engr.,
325 Montgomery St., San Francisco, Cal. '95

*BROWN, L. BLANCHARD, Min. Engr.........Union Club, New York, N. Y. '03

†BROWN, LEWIS V., Mgr., Blast Furnace.....Star Furnace Co., Jackson, Ohio. '90

*BROWN, RAYMOND B., Vice-Prest. and Genl. Mgr.,
Duquesne Reduction Co., Pittsburg, Pa. '95

*BROWN, R. GILMAN, Cons. Engr., Vice-Prest. and Genl. Mgr.,
Standard Consolidated Mining Co., 310 Pine St., San Francisco, Cal. '89

*BROWN, THOMAS E., Cons. Engr.,
Care Otis Elevator Co., 17 Battery Place, New York, N. Y. '04

*BROWN, T. FORSTER, Min. & Civ. Engr., Guildhall Chambers, Cardiff,
South Wales, Great Britain. '86

*BROWN, WILLIAM CLINTON, Cons. Engr.,
512 William St., Montreal, Canada. '95

*BROWN, WILLIAM F.................Calle de Cadena 14, Mexico City, Mexico. '02

*BROWN, WILLIAM S., Min. Engr., Pilgrims' Rest, Lydenburg,
Transvaal, South Africa. '94

*BROWNE, ARTHUR B., Cons. Min. Engr ....Sumpter, Oregon. '93

*BROWNE, DAVID H., The Orford Copper Co.,
New Brighton, Staten Island, N. Y. '00

†BROWNE, R. MONTAGUE, Civ. Engr..Launceston Club, Launceston, Tasmania. '96

*BROWNE, ROSS E., Min. Engr., Temporarily Care Wernher, Beit & Co.,
1 London Wall Bldgs., London, E. C., England. '94

*BROWNELL, EDWARD E., Mine Owner, 604 Montgomery St.,
San Francisco, Cal. '05

*BROWNING, WALTER JAS., Min. Engr., Genl. Mgr., Mazapil Copper Co.,
Ltd., Concepcion del Oro, Zacatecas, Mexico. '02

*BROWNLEE, ARCHIBALD G., Mine Expert, Care Stanley Mine,
Idaho Springs, Colo. '97

*BRUCE, JAMES L., Engr. of Mines..Care Federal Lead Co., Flat River, Mo. '03

*Bruce, Thomas C., Min. Engr., Barnato Consolidated Mines, Ltd., Consolidated Bldgs., Johannesburg, Transvaal, So. Africa. '03
**Brunton, D. W., Cons. Engr.........Room 506, Boston Bldg., Denver, Colo. '83
*Bryant, George W., Min. Engr...Apartado No. 25, Guanajuato, Mexico. '04
*Bryden, Charles L., Instructor..........402 Church St., Iowa City, Iowa. '04
*Buck, Arthur H., Min. Engr., Care The Continental Mining Co., Mineral "El Panuco," Monclova, Coahuila, Mexico. '03
†Buck, Laurence M............................261 Newbury St., Boston, Mass. '05
*Buck, Rufus, Min. Engr ....Dawson, Yukon Territory. '97
*Buck, Stuart M., Min. Engr., Prest. and Genl. Mgr., Sagamore Coal & Coke Co., Bramwell, W. Va. '71
†Buck, Victor B., Jr...Danbury, Conn. '98
**Buckley, Ernest R., State Geologist, Director of the Bureau of Geology and Mines, Rolla, Mo. '02
*Budrow, Lester R., Min. Engr., Care Tiro General Charcas, San Luis Potosi, Mexico. '02
*Budrow, W.B., Min. and Met. Engr., Calle de Santa Teresa, 103½ Guadalajara, Mexico. '00
**Bugbee Edward E., Teacher of Mining and Metallurgy, Iowa State College, Ames, Iowa. '05
*Buhl, Frank H., Capitalist................................E. State St., Sharon, Pa. '91
*Bukofzer, Edwin, Met..............................Instructed to hold all mail. '01
*Bulkley, Frank, Min. Engr............446 Equitable Bldg., Denver, Colo. '89
*Bulkley, Frederick G.........................Hotel Redondo, Redondo, Cal. '82
*Bulkley, Henry W...........................141 Broadway, New York, N. Y. '79
*Bull, Irving C., Anal. and Cons. Chem. and Met......Middletown, N. Y. '03
*Bullen, James, Mine Mgr., Pontywain-near-Newport, Monmouth, England. '04
*Bulley, Reginald H......................Halcomb Steel Co., Syracuse, N. Y. '78
*Bunker, Charles E......Supt., Yaeger Cannon Copper Co., Prescott, Ariz. '00
*Bunting, Douglas, Chief Engr., Lehigh & Wilkes-Barre Coal Co., Wilkes-Barre, Pa. '04
*Burbidge, Frederick, Min. Engr., Prest., Coeur d'Alene Development Co., Silver King, Idaho. '87
†Burbidge, Theodore A., Student....173 Rutledge Ave., Charleston, S. C. '04
*Burch, Albert, Min. Engr........510 Empire State Bldg., Spokane, Wash. '00
*Burchell, H. C., Supt. of Public Works, Belize, British Honduras, Central America. '83
†Burden, Henry, 2d., Prest., Cazenovia National Bank....Cazenovia, N. Y. '92
**Burden, H. H.......................Care Henry Burden, 2d, Cazenovia, N. Y. '83
*Burden, James A............................ ....Woodside, Troy, N. Y. '76
*Burdick, Edward H., Chem.............................Box 724, Victor, Colo. '03
*Burger, Clarence C., Min. Engr., Bradshaw Mountain Copper Mining & Smelting Co., 71 Broadway, New York, N. Y. '97
*Burgess, John DeW., Cons. Min. Engr........P. O. Box 747, Tucson, Ariz. '00
*Burhans, Harry H., Student, Michigan College of Mines, Houghton, Mich. '05
†Burke, M. D., Cons. Civil Engr., Room 18, 106 E. 4th St., Cincinnati, Ohio. '74
*Burlingame, Eugene E., Chem., Assayer and Bullion Dealer, E. E. Burlingame & Co., 1736–1738 Lawrence St., Denver, Colo. '82
*Burlingame, Walter E., Assayer and Chem..1259 York St., Denver, Colo. '01
*Burnand, Alphonse A.....Dairy Farm Mine, Van Trent, Placer Co., Cal. '03

*Burne, Cecil A.....San Carlos Copper Co., San José, Tamaulipas, Mexico. '04

*Burnham, Mather H...Straindrop Lodge, Chapeltown, Sheffield, England. '98

*Burnham, William, Prest. and Treas., The Standard Steel Works, 1103 Harrison Bldg., Philadelphia, Pa. '76

*Burns, Elmer Z., Min. Engr.................159 Front St., New York, N. Y. '04

*Burns, William J., Rolling Mill Supt., Park Works, Crucible Steel Co. of America, 30th and Smallman Sts., Pittsburg, Pa. '97

*Burns, Willis T., Genl. Foreman Electrolytic Copper Refinery, Boston and Montana Cons. Copper & Silver Mining Co., Great Falls, Mont. '03

*Burr, Guillermo A., Cons. and Min. Engr., Mgr., La Vencedora Gold Mining Co., Parral, Chihuahua, Mexico. '03

*Burrage, William H..Cañon City, Colo. '00

*Burrall, Frederick P., Min. Engr..Care Ayer & Longyear, Talent, Ore. '97

*Burrell, Alexander, Min. Mgr., Montana Mining Co., Ltd., Marysville, Mont. '92

*Burrell, Henry, Manager of Mines..... ....Edgemont, Nev. '00

*Burrows, Charles W., Chief Met., Smelting and Refining Co. of Australia, [1901] Ltd., Dapto, New South Wales, Australia. '99

*Burrows, R. H., Min. Engr., Care Mineral Development Co., Guanajuato, Mexico. '99

**Burt, Andrew......................Elphinstone Collieries, Tranent, Scotland. '99

**Burt, Charles S.....Cramer & Burt, 1114 Monadnock Bldg., Chicago, Ill. '82

*Bush, B. F...156 Laclede Bldg., St. Louis, Mo. '99

*Bush, E. Renshaw, Cons. Min. Engr.........69 Wall St., New York, N. Y. '85

*Bushell, Benj. D., Surveyor, Care General Mining & Finance Corporation, Johannesburg, Transvaal, South Africa. '02

*Butler, Chauncey E., Chem......................................Address wanted. '96

*Butler, Joseph G., Jr., Mnfr. and Miner................Youngstown, Ohio. '05

*Butler, William Curtis, Banker, Prest., First National Bank, Everett, Wash. '96

*Butters, Charles, Min. Engr. and Met............Roselawn, Berkeley, Cal. '83

*Byrnes, Owen..Marysville, Mont. '95

**Cabot, John, Jr............Care Robins Conveying Belt Co., Passaic, N. J. '99

*Cabot, John W., Cons. Met. Engr., Care F. E. Cabot, 85 Water St., Boston, Mass. '80

*Caetani, Gelasio, Civ. and Min. Engr.........,...............El Oro, Mexico. '04

*Cairns, Frederick I..Houghton, Mich. '97

*Caldecott, William A., Cons. Met., Consolidated Gold Fields of South Africa, P. O. Box 67, Johannesburg, Transvaal, So. Africa, '02

*Calderwood, James M., Cons. Engr., 31 Exploration Bldgs., Johannesburg, Transvaal, So. Africa. '96

*Caldwell, B. M., Retired.......................29 Broadway, New York, N. Y. '96

*Caldwell, William A., Met. Chem., 317 Onslow Drive, Dennistown, Glasgow, Scotland. '05

*Calero, José, Min. Engr., Real del Monte Mining Co., Las Cajas, Pachuca, Hidalgo, Mexico. '01

**Callaghan, John T., Jr., Min. Engr. and Met., 613 W. 7th St., Chester, Pa. '96

*Cameron, William McC., Mine Mgr., Genl. Mgr., The May Cons. Gold Mining Co., Ltd., P. O. Box 50, Germiston, Transvaal, So. Africa. '97

*Camm, Robert, Min. Engr......Gauley Mountain Coal Co., Ansted, W. Va. '00

*Camp, James M., Chem..................Duquesne Steel Works, Duquesne, Pa. '88
*Campbell, David H., Min. Engr. and Met..................Houghton, Mich. '03
*Campbell, E. D..................................108 Hill Street, Ann Arbor, Mich. '93
*Campbell, Frank J., Secy. and Mgr., The Vindicator Consolidated Gold Mining Co., etc., 302 Boston Block, Denver, Colo. '99
*Campbell, Harry H., Genl. Mgr.....Pennsylvania Steel Co., Steelton, Pa. '81
†Campbell, Joseph C., Atty. at Law.....Crocker Bldg., San Francisco, Cal. '03
*Campbell, Marius R., Geol....U. S. Geological Survey, Washington, D. C. '92
**Campbell, William, Met. Research, Columbia University, New York, N. Y. '03
*Camphuis, George A., Min. Engr........San Domingos, Mertola, Portugal. '01
*Canby, R. C..............................334 South Main St., Wallingford, Conn. '82
*Canfield, Chauncey L., Mine Mgr., 635 Market St., San Francisco, Cal. '03
*Canfield, Frederick A., Min. Engr...............................Dover, N. J. '74
*Cannon, R. M., Civ. and Min. Engr...................Colorado Springs, Colo. '04
*Caperton, W. Gaston, Genl. Mgr., Secy. & Treas., Wrigh Coal & Coke Co., Wright, W. Va. '94
*Capp, John A., Chief of Testing Laboratory, General Electric Co., Schenectady, N. Y. '96
*Caracristi, C. F. Z., Civ. and Min. Engr., 50 Broadway, New York, N. Y. '01
*Cardozo, Henri A.......................62 Rue de Tocqueville, Paris, France. '98
*Carhart, Winfield S., Min. Engr...........P. O. Box 165, Telluride, Colo. '95
*Carleton, James G., Min. Engr.............25 State St., Marblehead, Mass. '92
*Carlsson, Hugo, Ingenior vid Jerkontoret Smålandsgatan, 42, Stockholm, Sweden. '97
*Carlyle, William A., Min. Engr., Genl. Mgr., Cia. de Rio Tinto, Ltd., Minas de Rio Tinto, Province de Huelva, Spain. '96
*Carmichael, Henry, Chem. and Met., Room 520, Weld Bldg., 176 Federal St., Boston, Mass. '00
*Carmichael, Norman, Min. Engr. and Assayer, Care Arizona Copper Co., Morenci, Ariz. '99
*Carnahan, Charles T., Mine Owner and Operator, The Resurrection Gold Mining Co., Leadville, Colo. '89
*Carnahan, John S., Mine Supt., Mexican Lead Co., Monterey, N. L., Mexico. '97
Carnegie, Andrew...............................2 E. Ninety-first St., New York, N. Y.
*Carney, Hugh J., Min. Student.......................................Ouray, Colo. '04
*Carpenter, Alvin B., Min. Engr., Mgr., 1st Independencia Num. 36 Mexico City, Mexico. '97
*Carpenter, Frank, Metallurgist, 7435 Boyer St., Mt. Airy Station, Philadelphia, Pa. '98
*Carpenter, Prof. F. R., Civ. Min. Engr. and Met., 1420 Josephine St., Denver, Colo. '87
*Carpenter, Laurence B., Cons. Engr...............................Basin, Ariz. '05
*Carpenter, Rolla C., Prof., Experimental Engineering, Cornell University, Ithaca, N. Y. '00
*Carr, Henry C., Min. Engr.............38 Fremont St., San Francisco, Cal. '05
*Carr, Percy E. O., 16 Holmdale Road, West Hampstead, London, N. W., England. '92
*Carrigan, Andrew, Merchant............... 17 Beale St., San Francisco, Cal. '99
*Carroll, Lafayette D., Gas Engr., Care Humphreys & Glasgow, 38 Victoria St., London, S. W., England. '88
*Carry, Henry E. C., Civ. and Min. Engr., 877 Dorchester St., Montreal, Quebec, Canada. '97

*CARSON, ARTHUR C., Mining Supt.....Speculator Mining Co., Butte, Mont. '84

*CARSON, GEORGE C., Min. and Met. Engr...Hotel Bradway, Denver, Colo. '03

*CARTER, BENJAMIN P., Min. Engr., Genl. Mgr., Ferreira Gold Mining Co.,
P. O. Box 1021, Johannesburg, Transvaal, So. Africa. '95

*CARTER, HENRY M., Met.................480 West 4th Ave., Columbus, Ohio. '02

**CARTER, THOMAS LANE, Min. Engr., French Rand Gold Mining Co.,
Box 25, Luipards Vlei, Transvaal, So. Africa. '03

*CARVER, LEONARD H., Hydraulic and Min. Engr.,
Mountain Gold Mines Co., 503 California St., San Francisco, Cal. '03

*CASE, BENJAMIN H., Min. Engr.................................Copperhill, Tenn. '03

*CASE, CHARLES M., Stocks and Bonds, Whallon, Case & Co.,
58 Chamber of Commerce, Minneapolis, Minn. '96

*CASE, W. H., Mine Mgr...Address wanted. '04

*CASEY, JOHN P., Min. Engr.........................Cananea, Sonora, Mexico. '03

*CATES, LOUIS S., Min. Engr., Supt., Boston Cons. Mining Co.,
Bingham Canyon, Utah. '04

*CATLETT, CHARLES, Chem., Geol. and Min. Expert.............Staunton, Va. '95

**CATLIN, ROBERT M., Min. Engr., Genl. Mgr., Consolidated Gold Fields,
S. A., Ltd., Box 1167, Johannesburg, Transvaal, So. Africa. '00

*CAUTLEY, ARTHUR O., Min. Engr., Cosmopolitan Proprietary and
Affiliated Companies, 139 Cannon St., London, England. '03

*CAZIN, FRANZ, Cons. Mech. Engr., Rooms 400 and 401, Jackson Bldg.,
Denver, Colo. '89

*CERRINA-FERONI, PAOLO, Mine Mgr.,
Boccheggiano-Miniera-Grosseto, Italy. '04

*CHALMERS, GEORGE, Min. Engr., Supt., St. John del Rey Mining Co., Ltd.,
Morro Velho, Villa Nova de Lima, Minas Geraes, Brazil, So. America. '92

**CHALMERS, JOHN A., Min. Engr.,
The Club, Bulawayo, Rhodesia, So. Africa. '95

*CHALMERS, WILLIAM J., Vice-Prest., Allis-Chalmers Co.,
New York Life Bldg., Chicago, Ill. '94

*CHAMBERLAIN, H. S., Mfgr. and Miner, Prest., Roane Iron Co.,
Chattanooga, Tenn. '75

*CHAMBERS, ROBERT E., Mgr., Ore Mines and Quarries. The Nova Scotia
Steel and Coal Co., Ltd., New Glasgow, Nova Scotia. '91

*CHAMBOST, PIERRE J. E. E., Engr. of Mines, Care Messrs. Sautter Harle,
26 Ave de Suffren, Paris, France. '03

*CHANCE, DR. H. MARTYN, Cons. Min. Engr.,
819 Drexel Bldg., Philadelphia, Pa. '74

*CHANDLER, CHARLES F., Prof. of Chemistry, Columbia University,
New York, N. Y. '90

*CHANNING, J. PARKE, Cons. Min. Engr., Prest., Tennessee Copper Co.,
11 Broadway, New York, N. Y. '84

*CHANNING, ROSCOE H., JR., Mgr., Utah Consolidated Mining Co.,
405 Dooly Bldg., Salt Lake City, Utah. '04

*CHANUTE, O., Cons. Engr., Prest., Chicago Tie Preserving Co.,
94th St. and Chicago, Rock Island and Pacific R. R. tracks, Chicago, Ill. '79

*CHAPLIN, GEORGE P., Min. Engr., 96 Breakspears Road, Brockley,
London, S. E., England. '97

*CHAPMAN, CHARLES W., Pastoralist,
39 Queen St., Melbourne, Victoria, Australia. '91

*Chapman, James E., Mine Surveyor, Casilla 336, Guayaquil, Ecuador, South America. '04

*Chapman, Melville D., Banker and Broker, E. R. Chapman & Co., 80 Broadway, New York, N. Y. '00

*Chapman, Norman W., Min. Engr...........117 Cherry St., Seattle, Wash. '03

*Chapman, Robert H., Topographer, U. S. Geological Survey, Washington, D. C. '97

*Chappell, Howard F., 3d Vice-Prest., General Chemical Co., 25 Broad St., New York, N. Y. '94

*Charleton, A. G., Cons. Min. Engr., Mansion House Chambers, Queen Victoria St., London, E. C., England. '81

*Chase, Arthur W., Capt. Army Corps, U. S. A., Army and Navy Club, 16 W. 31st St., New York, N. Y. '03

*Chase, Charles A., Supt...Liberty Bell Gold Mining Co., Telluride, Colo. '00

**Chase, Edwin E., Min. Engr.............932 Equitable Bldg., Denver, Colo. '03

*Chase, Frank D.....................................34 Moreland St., Boston, Mass. '84

*Chatard, Thomas M., Cons. Chem., 1716 Rhode Island Ave., Washington, D. C. '88

*Chauvenet, Regis, Min. Engr..........937 Equitable Bldg., Denver, Colo. '03

*Chauvenet, S. H., Mgr., Berkshire Iron Works................Sheridan, Pa. '81

*Chauvenet, William M., Min. Engr. and Chem., Regis Chauvenet & Bro., 620 Chestnut St., St. Louis, Mo. '90

*Chenhall, J. Warne, Min. and Met. Engr.....P. O. Box 218, Shelby, N. C. '05

*Chenhall, James W., Cons. Civ. Min. and Met. Engr., Totnes, Devonshire, England. '85

*Chennells, J. Arnott, Min. Engr., Mgr., Gulong Gold Mining Co., Ltd., Gulong, Southern Rhodesia, So. Africa. '02

*Chesebrough, George L.........................Lyceum Bldg., Duluth, Minn. '97

*Chester, Edward D., Cons. and Min. Engr., 20 Copthall Ave., London, E. C., England. '90

*Chevrillon, Louis, Min. Engr..........Apartado 18, Mexico City, Mexico. '02

*Cheyney, Samuel W., Min. Engr. and Genl. Mgr., Jamison Mining Co., Alta Sierra Gold Mining Co., etc., 620 Hayward Bldg., San Francisco, Cal. '87

*Chibas, Eduardo J., Civ. and Min. Engr. and Contractor, Apartado 110, Santiago de Cuba, Cuba. '96

*Chibas, Luis F., Engineer and Contractor, Jefatura de Minas, Santiago de Cuba, Cuba. '01

*Child, Alfred T., Met., Eilers' Plant, American Smelting & Refining Co., Pueblo, Colo. '00

**Chippendale, Arthur, Chemist, American Club, Mexico City, Mexico. '99

*Chisholm, John, Met., Care Omai Gold Mining Co., Georgetown, British Guiana, South America. '00

**Choate, Wayne, Min. Engr...Riverside, Cal. '02

*Chouteau, Pierre, Prest., Iron Mountain Co., Security Bldg., St. Louis, Mo. '76

**Christian, August, Chief Engr., Min. Dept., Anaconda Copper Mining Co., Butte, Mont. '99

*Christiansen, Herman B., Chem...Rome, Ga. '95

*Christianson, Peter, Instructor in Metallurgy, Minnesota School of Mines, 411 Walnut St., S. E., Minneapolis, Minn. '01

*Christy, Samuel B., Prof. of Min. and Met., University of California, Berkeley, Cal. '83

*Church, Albert K., Mgr., American Dept., National Tube Co., Middletown, Pa. '92

*Church, E. D., Jr., Secy., Church & Dwight Co.,
63 Wall St., New York, N. Y. '88
*Church, Prof. John A., Min. Engr.......15 William St., New York, N. Y. '72
†Church, Myron J., Min. Engr ....Victor, Col. '97
†Chynoweth, B. F...Houghton, Mich. '76
*Claghorn, Clarence R.,
Northwestern Improvement Co., Headquarters Bldg., Tacoma, Wash. '84
*Clapp, George H., Chairman, Pittsburg Testing Laboratory, Ltd.,
325 Water St., Pittsburg, Pa. '83
*Clark, Allan J., Chief Assayer...Homestake Mining Co., Lead, So. Dak. '97
*Clark, Carle D., Asst. District Supt.,
Care Arizona Copper Co., Morenci, Ariz. '03
*Clark, Clarence M., Banker, E. W. Clark & Co., Bullitt Bldg.,
Philadelphia, Pa. '88
*Clark, Edward W., Supt., Ophir Hill Consolidated Mining Co.,
Ophir, Utah. '04
*Clark, Edwin M., Supt. of Smelter, 1982 Bonsallo Ave., Los Angeles, Cal. '91
†Clark, Frederick..................................Mills Bldg., San Francisco, Cal. '98
*Clark, George C., Min. Engr.........94 West 104th St., New York, N. Y. '01
*Clark, George M., Min. Supt., River Hill Mining and Milling Co.,
Placerville, Cal. '99
*Clark, James M., Civ. and Min. Engr., Care Clark & Krelis,
Kanawha Falls, W. Va. '02
*Clark, Josiah H., Min. Engr..................18 Wall St., New York, N. Y. '98
*Clark, Lindesay C., Min. Engr., Genl. Mgr., The Briseis Mines, Ltd.,
Derby, Tasmania. '99
**Clark, Maurice, Assayer......................Apartado 233, Oaxaca, Mexico. '86
*Clark, V. V., Min. Engr..Box 284, Galena, Ill. '99
*Clark, Walton, Gas Engr., Gen. Supt., The United Gas Imp. Co.,
Broad and Arch Sts., Philadelphia, Pa. '96
*Clark, William A., Banker, Mining, Mill Owner, etc..........Butte, Mont. '82
*Clark, Will L., Asst. Genl. Mgr., United Verde Copper Co..Jerome, Ariz. '03
*Clarke, E. A. S., Care Lackawanna Steel Co.,
100 Broadway, New York, N. Y. '85
*Clarke, Hopewell..........................775 Portland Ave., St. Paul, Minn. '96
*Clarke, Roy H., Min. Engr...Room 3, Wolverton Bldg., Spokane, Wash. '01
*Clarke, William B., Elect., Min. Engr., General Electric Co.,
Schenectady, N. Y. '02
*Claudet, Arthur C., Chem. and Met. Assayer to the Bank of England,
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*Claudet, H. Hayman, Met. Engr., Tech. Rep., Canadian Ore Concentration,
P. O. Box 578, Rossland, B. C., Canada. '03
*Claypool, W. M., Min. Engr., Prescott Agency,
Am. Smelting & Refining Co., Prescott, Ariz. '84
*Cleaveland, Newton, Genl. Supt., Guba Consolidated Gold Fields,
Marysville, Montana. '01
*Cleland, E. Davenport, 966 Rhode St., Kalgoorlie, Western Australia. '90
*Clemens, Fred L., Min. Engr..........................Box 200, Durango, Colo. '04
*Clement, F. H., Civ. Engr...............124 West 48th St., New York, N. Y. '92
*Clement, Harrison Edward, Min. Engr.,
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*Clements, J. Morgan, Economic Geol. and Min. Engr., 15 William St., New York, N. Y. '01
**Clemes, John H., Min. Engr., The Bracken, Newquay, Cornwall, England. '81
*Clerc, F. L. .... The Shirley Hotel, Denver, Colo. '87
*Cleveland, Ernest A. .... Vancouver, B. C., Canada. '03
*Clevenger, Galen H., Met. .... Box 321, Palo Alto, Cal. '03
**Cliff, Capt. John, Retired Mining Captain, 1309 Second St., San Diego, Cal. '80
*Clouston, T. Harold, Genl. Mgr., Ringarooma Tin Mine, Ltd., Derby, Tasmania. '01
*Clymer, Edward T. .... 806 North 63d St., Philadelphia, Pa. '82
*Clymer, Frederick H., Min. Engr. .... 249 N. Fifth St., Reading, Pa. '97
*Cobb, Harald McL., Min. Engr., National Metal Co., Guanacevi, Durango, Mexico. '04
*Cobb, William L., Min. Engr., Mill Supt., Kalgwarli Gold Mines, Ltd., 425 Crossley Bldg., San Francisco, Cal. '03
*Cobbe, Hervic N. G., Mill Supt., Kalgurli Gold Mines, Kalgoorlie, Western Australia. '01
*Cockerell, Leslie M. .... Apartado No. 157, Guadalajara, Mexico. '00
*Codington, Edmund W., Prest., American Mining and Improvement Co., Bartow, Florida. '90
*Coe, Ira J., Cement and Min. Engr. .... 177 E. Mass. Ave., Oakland, Cal. '03
*Coe, William W., Genl. Mgr., Pocahontas Coal & Coke Co.. Roanoke, Va. '83
*Coffin, Charles E., Charcoal Pig Iron Mfr. .... Muirkirk, Md. '82
*Coffin, William C., Vice-Prest., Riter Conley Mfg. Co., 5930 Howe St., Pittsburg, Pa. '92
**Cogswell, William B., Vice-Prest. and Managing Director, Solvay Process Co., Syracuse, N. Y. '72
**Cohen, E. H. A., Cons. Min. Engr. and Mgr., Rand Club, Johannesburg, Transvaal, So. Africa. '94
*Cohen, H. A., Min. Engr. .... 210 Crocker Bldg., San Francisco, Cal. '89
*Cohen, Louis, Min. Engr. .... 417 Jackson Bldg., Denver, Colo. '01
*Colbath, Harry, Mill Supt. .... Care L. U. Colbath, Salt Lake City, Utah. '00
*Colbath, L. U., Mining .... P. O. Box 717, Salt Lake City, Utah. '87
*Colby, Albert Ladd, Met. Engr., Asst. to Prest, International Nickel Co., 43 Exchange Place, New York, N. Y. '83
*Colby, Safford K., Civ. Engr., Pittsburg Reduction Co., 99 John St., New York, N. Y. '00
*Cole, Arthur A., Assayer and Chemist, Centre Star Mining Co., Rossland, B. C., Canada. '02
*Cole, David, Min. Engr., Supt., Concentration Dept., Cananea Consolidated Copper Co., Cananea, Sonora, Mexico. '05
*Cole, Frank L., Min. Engr. .... American Consulate, Shanghai, China. '04
*Cole, T. F., Prest., Oliver Iron Mining Co. and Minnesota Iron Co., Wolvin Bldg., Duluth, Minn. '90
*Coleman, Bertrand Dawson .... Lebanon, Pa. '95
*Coleman, Robert J., Min. Engr., Care Engineer's Club, 374 Fifth Ave., New York, N. Y. '03
*Coleman, R. Prewitt, Min. Engr., 930 East Ocean Ave, Long Beach, Cal. '03
**Collbran, Arthur H., Min. Engr. ....,...................... Seoul, Korea. '05
*Colley, Bernard T., Asst. Supt., American Smelting & Refining Co., Aguascalientes, Mexico. '88

*COLLIER, JOHN H., JR., Min. Engr., Supt., Lassen Mining Co., Haydenhill, Lassen Co., Cal. '00

**COLLIN, EMILE C., Mgr., Cie. des Mines et Usines d'Escombrera, Bleyberg (Spain and Belgium), 49 Rue de Miromesnil, Paris, France. '86

*COLLINGS, BURTON I., Care Harvey & Co., P. O. Box 1279, Johannesburg, Transvaal, So. Africa. '02

†COLLINGWOOD, FRANCIS, Cons. Engr., and Expert Civil Service Examiner, Elizabeth, N. J. '82

*COLLINS, EDGAR A., Min. Engr., Supt., Combination Mines Co., Goldfield, Nev. '04

†COLLINS, FRANCIS W., Student of Mining Engineering, Care New York Athletic Club, 58 W. 59th St., New York, N. Y. '03

**COLLINS, GEORGE E., Min. Engr............217 Boston Bldg., Denver, Colo. '00

**COLLINS, HENRY F., Min. and Met. Engr., Cerro Muriano Mines, Ltd., Estacion de Cerro Muriano, Provincia de Cordoba, Spain. '96

*COLLINS, HORACE F.......................Apartado 174, Mexico City, Mexico. '00

*COLLINS, JOHN P., Blast Furnace Supt.....222 Mathilda St., Pittsburg, Pa. '05

*COLLINS, W. J................Box 3253, Johannesburg, Transvaal, So. Africa. '93

*COLLORD, GEORGE L., Supt. of Blast Furnaces, Clairton Works, Carnegie Steel Co., Clairton, Pa. '01

**COLQUHOUN, JAMES, Prest..................Arizona Copper Co., Clifton, Ariz. '98

*COLTON, CHARLES A., Director, Newark Technical School, 367 High Street, Newark, N. J. '74

**COLVIN, VERPLANCK, Box No. 1, Capitol. (House 175 Western Ave.), Albany, N. Y. '81

*COLWELL, ALFRED B., Min. Engr., Room 26, Mining Exchange Bldg., Cripple Creek, Colo. '03

*COLYAR, LOUIS S., Prest., Eagle Iron Co., Rome Furnace Co., etc., Chattanooga, Tenn. '85

*COMING, GEORGE R., Min. Engr.................Greaterville, Pima Co., Ariz. '05

*COMSTOCK, CHARLES W., Civ. and Min. Engr., 213 Boston Bldg., Denver, Colo. '00

*COMSTOCK, PROF. THEODORE B., Cons. Min. Engr., 534 Stimson Bldg., Los Angeles, Cal. '80

*CONANT, H. D., Supt., Lake Superior Smelting Co..........Dollar Bay, Mich. '88

*CONLEY, OWEN J., Min. Engr..................18 Broadway, New York, N. Y. '02

*CONNER, ELI T., Min. Engr., Mgr., Pennsylvania Coal & Coke Co., Cresson, Pa. '92

*CONNER, JOHN T., Mine Supt................"The Monticello," Helena, Mont. '00

*CONNOR, CHARLES, Supt., Stonegap Colliery Co..Glamorgan, Wise Co., Va. '86

**CONNOR, S. B., Prest., El Oro Dredging Co., etc., Mills Bldg., San Francisco, Cal. '88

*CONRADSON, PONTUS H., Chief Chemist, Galena Signal Oil Works, Franklin, Pa. '92

*COOK, EDGAR S............Prest., Warwick Iron and Steel Co., Pottstown, Pa. '77

*COOK, EDWARD H., Min. Engr., Supt., American Smelting & Refining Co., Asientos, Aguascalientes, Mexico. '96

*COOK, ROBERT A., Portland Cement, Room 18, 229 Broadway, New York, N. Y. '83

*COOKE, HENRY M. A., Min. Engr., The Champion Reefs Gold Mining Co., Champion Reefs, Mysore, South India. '01

**COOKE, LEWIS H.........Royal School of Mines, London, S. W., England. '01

*COOLIDGE, WALTER G., Copper Ref., Chicago Copper Refining Co.,
310 Western Union Bldg., Chicago, Ill. '82

†COOMBS, HAROLD L. ....Galt, Cal. '02

††COOPER, JAMES B., Supt., Calumet and Hecla Smelting Wks.,
Hubbell, Mich. '99

**COOPER, JOHN, Supt. of Mines, Mazapil Copper Co., Ltd.,
Concepcion del Oro, Zacatecas, Mexico. '03

*COPELAND, F. K., Prest., Sullivan Machinery Co., Railway Exchange,
Chicago, Ill. '87

**CORBOULD, WILLIAM HENRY, Genl. Mgr., The "Lloyd" Copper Co., Ltd.,
Burraga, New South Wales, Australia. '92

*CORBUS, A. W.....................................1511 Jones St., San Francisco, Cal. '00

**CORBUS, J. PARKER...........Room 30, 6 California St., San Francisco, Cal. '96

*COREY, W. E., Prest., United States Steel Corporation,
71 Broadway, New York, N. Y. '94

*CORNELIUS, WILLIAM A., Asst. Mgr., Natl. Dept.,
National Tube Co., McKeesport, Pa. '01

*CORNELL, RUSSELL T., Min. Engr.......67 West 83d St., New York, N. Y. '02

*CORNING, C. R., Min. and Cons. Engr...........36 Wall St., New York, N. Y. '86

*CORNING, FREDERICK G., Min. Engr., Prest and Managing Director of
Companies, 35 Wall St., New York, N. Y. '77

*CORNISH, HARRY L., Min. Engr.......................Box 634, San José, Cal. '03

†CORRY, ARTHUR V., Min. Engr......................P. O. Box 323, Butte, Mont. '97

*CORWIN, GEORGE F., Chem. and Met.............Instructed to hold all mail. '03

*CORYELL, TORBERT, Min. Engr., Supt., Union Imp. Co. of Hazleton, Pa.,
Lambertville, N. J. '83

*COSBY, FREDERICK N., Min. Engr., Ymir Gold Mine,
Ymir, B. C., Canada. '03

*COSBY, R. PARKYN, Min. Engr......................Sekondi, West Coast, Africa. '03

*COSENS, JOHN DICKSON, Min. Engr.........Tank Mine, Oorgaum, So. India. '95

*COSGRO, JNO. P., Master Mech., Care Allis-Chalmers Co.,
New York Life Bldg., Chicago, Ill. '01

*COSTE, EUGÈNE, Min. Engr. and Geol., Prest., Canadian Mining Institute,
Canada Permanent Bldg., 18 Toronto St., Toronto, Ontario, Canada. '87

**COUMERILH, WILLIAM, Mine Operator...........................Mullen, Idaho. '95

*COURTIS, W. M., Cons. Met. Engr., Treas., U. S. Potash Co., Ltd., etc.,
412 Hammond Bldg., Detroit, Mich. '71

**COURTNEY, CHARLES F., Civ. and Min. Engr., Sulphide Corporation, Ltd.,
34 Queens St., Melbourne, Victoria, Australia. '97

*COWAN, JAMES I., Min. Engr................Box 456, Colorado Springs, Colo. '99

*COWLES, ALFRED H., Prest., Cowles Elect. Smelting & Aluminum Co.,
Pecos River Mining Co., 361 The Arcade, Cleveland, Ohio. '86

*COX, HERBERT B., Asst. to the Prest., Empire Steel & Iron Co.,
Catasaqua, Pa. '04

*COX, JENNINGS S., JR., Genl. Mgr., Spanish-American Iron Co.,
Santiago de Cuba, Cuba. '99

†COX, STERLING B...............................67 Harrison St., East Orange, N. J. '01

*COX, THOMAS, Cons. Engr........................170 N. 16th St., Portland, Ore. '01

*COX, WILLIAM J., Genl. Mgr., Camp Bird, Ltd...................Ouray, Colo. '93

*COX, W. RAY, Min. Engr., Assayer and Chemist,
P. O. Box 717, Goldfield, Nev. '03

*COX, W. ROWLAND, Mine Manager, Silver Lake Mines......Silverton, Colo. '03

†Coxe, Alexander B., Coal Operator....Coxe Bros. & Co., Inc., Drifton, Pa. '80
*Coxe, Charles E., Ore Buyer..Apartado 17, Zacatecas, Zacatecas, Mexico. '00
**Coxe, Eckley B., Jr..................Anthracite Coal Operator, Drifton, Pa. '93
*Crafts, Walter N., Manufacturer of Machinery, 56 East Prospect St., Cleveland, Ohio. '95
*Cragoe, A. Spencer, Min. Engr., 2 Silchester Road, St. Leonard's-on-Sea, Sussex, England. '97
*Crandall, W. R...Address wanted. '86
*Crane, Gerard A., Min. Engr., No. 6 Great Winchester St., London, E. C., England. '04
†Crane, Theron I., Iron and Steel, 600 Girard Trust Bldg., Philadelphia, Pa. '92
*Crane, Walter R., Columbia University....................New York, N. Y. '00
*Cranston, Robert E., Mine Mgr., Ashburton Mining Co..Sacramento, Cal. '73
*Crawford, George G., Mgr., National Tube Co..............McKeesport, Pa. '00
*Crawford, Henry E., Min. Engr.......................Hanover, New Mexico. '02
*Crawford, John J., Met. and Min. Engr., Director and Secy., Gwin Mine Development Co. of California, etc., 1209 Call Bldg., San Francisco, Cal. '73
*Crawford, John L., Chem.................26 S. Jefferson St., Newcastle, Pa. '84
*Crawford, Walter H., Min. Engr., Homestead Bldg., 218 Union St., Nashville, Tenn. '05
*Cremer, Felix, Mgr., Pittsburg Metallurgical Co.........Beaver Falls, Pa. '00
*Cremer, J. H......................................24 Superior St., Cleveland, Ohio. '75
*Crespi, R. A., Mine Owner......Puntarenas, Costa Rica, Central America. '05
*Creveling, James G., Jr..............Apartado 24, Aguascalientes, Mexico. '03
*Crewe, Leonard C................................Equitable Bldg., Denver, Colo. '03
*Crichton, Donald G., Met............Nundle, New South Wales, Australia. '89
*Crockard, Frank H., Mgr., Riverside Dept., National Tube Co., Wheeling, W. Va. '95
**Crocker, A. L., Mech. Engr.....2515 Blaisdel Avenue, Minneapolis, Minn. '80
*Crocker, George A., Iron Merchant..........99 John St., New York, N. Y. '79
*Croft, Henry, Cons. Engr...............................Victoria, B. C., Canada. '00
*Cromwell, Robert H., Min. Engr...................Arispe, Sonora, Mexico. '03
*Crooke, Robert L..............................234 Pearl St., New York, N. Y. '89
*Crooker, Ralph, Jr., Cons. Engr., 401 Columbia Bank Bldg., Pittsburg, Pa. '81
*Crookston, A. W., Min. Engr. and Mine Owner, 188 St. Vincent Street, Glasgow, Scotland. '80
*Crosby, William O., Prof. of Geol., Massachusetts Institute of Technology, Boston, Mass. '03
*Cross, Charles M., Min. Engr.......................................Address wanted. '03
*Crow, Thomas B., Assayer and Chemist, Care Mrs. R. H. Tatlow, 1220 Pearl St., Denver, Colo. '00
*Crowell, Benedict, Min. Engr., etc., Crowell & Peck......Cleveland, Ohio. '93
*Croxton, David T., Min. Engr., Genl. Mgr., Cleveland Furnace Co., 1314 Rockefeller Bldg , Cleveland, Ohio. '93
*Croxton, Samuel W., Iron Mfr., Prest. and Genl. Mgr., The Pennsylvania Iron & Coal Co., 1314 Rockefeller Bldg., Cleveland, Ohio. '75
*Cruikshank, Barton, Designing Engineer, Solvay Process Co., Syracuse, N. Y. '03
**Cuevas, Luis G., Assayer..........Apartado 148, San Luis Potosi, Mexico. '97
*Cullum, J. Barlow, 2d Vice-Prest., Harbison-Walker Co., Farmers' Bank Bldg., Pittsburg, Pa. '91

*Cummings, George P., Civ. and Min. Engr....................Marquette, Mich. '81
*Cummings, William N., Min. Engr. & Met., Apartado No. 2, Guanajuato, Mexico. '93
*Cummins, Leon, Cyanide Chemist and Elec. Engr., Union Iron Works Co., 222 Market St., San Francisco, Cal. '00
*Cunningham, Eckley S..Drifton, Pa. '99
*Cunningham, James S...........................506 Grove Ave., Johnstown, Pa. '83
*Cunningham, John C., Engr., Care Broken Hill, South Silver Mining Co., Broken Hill, New South Wales, Australia. '04
*Cunningham, Parker H., Min. Engr..305 Colorado Bldg., Denver, Colo. '05
*Currie, David, Min. and Met. Engr., Lake & Currie, Norfolk House, 7 Laurence Pountney Hill, London, E. C., England. '00
**Currie, Walter, Cons. Min. Engr., Willoughby's Consolidated Co., Ltd., Bulawayo, Rhodesia, So. Africa. '96
*Curtis, Uri B., Mine Supt. and Mgr., Prest., Crystal Water Co. and Alpine-Eagle Mining Co., Tonopah, Nev. '03
*Cutting, Charles H...Newburyport, Mass. '01

*Dabb, Charles E., Min. Engr., No. 1 Plain au gwarry Redruth, Cornwall, England. '03
*Daggett, Ellsworth, Min. Engr...........................Salt Lake City, Utah. '73
*Dakin, Frederick H. J., Min. Engr., The Dakin Co., 104 Sutter St., San Francisco, Cal. '04
†Dalburg, Frank A...State College, Pa. '04
*Daly, Herbert J., Min. Engr., Consolidated Mines Selection Co., Ltd., Prells Bldg., 60 Queen Street, Melbourne, Victoria, Australia. '98
*Dan, Takuma, Managing Director, Mitsui Mining Co., No. 2, Suruga-Cho Nihombashi-Ku, Tokio, Japan. '88
*Dana, Richard T., Cons. Engr............15 William St., New York, N. Y. '04
*Dane, Edward G...43 Arundel Mansions, Fulham Road, London, England. '02
*Danforth, A. H...Florence, Colo. '82
*Daniel, James M., Jr.................Apartado 16, Aguascalientes, Mexico. '04
*Daniel, William B., Min. Engr. and Mgr., Union Zinc & Lead Co., Shullsbury, Wis. '00
*Daniels, Frederick H., Chief Engr., Am. Steel & Wire Co., 214 Salisbury St., Worcester, Mass. '76
*Daniels, George P., Mine Supt....Whipple Colliery Co., Whipple, W. Va. '03
*Darby, Thomas L., Min. Engr.....................2538 Vine St., Denver, Colo. '98
*Darlington, Henry..................................Fidelity Bldg., Pittsburg, Pa. '90
*Darlington, Wayne..Stedman, Cal. '95
*Darsie, James, Vice-Prest. and Genl. Mgr., The Hecla Coke Co., 401 Wood St., Pittsburg, Pa. '93
*Dart, Albert C., Jr., Chemist for Newhouse Mines & Smelter Co., Newhouse, Utah. '02
*Darton, N. H., Geol...............U. S. Geological Survey, Washington, D. C. '94
**Davey, George, Min. and Met. Engr., 34 Carlton Vale, Maida Vale, London, W., England. '91
*David, W. M., Supt. of Smelting and Ref. Copper, Tottenville Copper Co., Tottenville, Staten Island, N. Y. '88
*Davidson, George M., Chem. and Engr. of Tests, Chicago & North Western Ry. Co., Chicago, Ill. '81
*Davidson, Otto C., Genl. Supt., Iron Mines, Oliver Iron Mining Co., Iron Mountain, Mich. '91

*DAVIES, WILLIAM H., Div. Supt., Lehigh Valley Coal Co....Hazleton, Pa. '97

*DAVIS, ARTHUR E., Mine Manager, La Palma Mining Co., Guatimapé, Durango, Mexico. '03

*DAVIS, BRITTON, Mine Owner and Mgr., Prest., Jaurez Co., etc., El Paso, Texas. '90

*DAVIS, CARL R., Min. Engr., Genl. Mgr., Lancaster Gold Mining Co., Ltd., Krugersdorp, Transvaal, South Africa. '99

*DAVIS, CHARLES H., Cons. Engr.................25 Broad St., New York, N. Y. '00

*DAVIS, CHARLES S.......................Cayuca de Catalan, Guerrero, Mexico. '01

*DAVIS, CHARLES W............................407 Cedar Lane, Edgeworth, Pa. '02

*DAVIS, F. HARLEY, Care Davis Drilling & Prospecting Co., Room 1038, First Nat. Bank Bldg., Birmingham, Ala. '99

*DAVIS, FLOYD, PH.D., Cons. Min. Engr. and Met., Iowa Loan & Trust Bldg., Des Moines, Iowa. '83

*DAVIS, FRANK S., Min. Engr., Supt., Consolidated Coal & Coke Co., Fort Lupton, Colo. '01

*DAVIS, GEORGE C., Anal. and Cons. Chem.....39 S. 10th St., Philadelphia, Pa. '93

*DAVIS, HERMAN, Prest. and Mgr., Nevada Reduction Works, Dayton, Nev. '01

*DAVIS, JAMES C., Genl. Mgr., American Steel Foundries....Granite City, Ill. '98

*DAVIS, LEWIS K., Cons. Engr.................512 Frick Bldg., Pittsburg, Pa. '93

*DAVIS, MORGAN, JR., Min. Engr., Rooms 42 and 43 Coal Exchange, Scranton, Pa. '98

*DAVIS, STEWART A., Asst. to 1st Vice-Prest., American Sheet Steel & Tin Plate Co., Pittsburg, Pa. '01

*DAVIS, WILLIAM C., Mgr., F. M. Davis Iron Works Co., 8th and Larimer Sts., Denver, Colo. '89

*DAVISON, GEORGE L., Asst. Supt., South Works, Illinois Steel Co., South Chicago, Ill. '97

*DAW, JOHN W., Civ. and Min. Engr., Walreddon Manor, Tavistock, Devon, England. '93

*DAWBARN, GILBERT J., Lecturer in Mining, School of Mines, Ballarat, Victoria, Australia. '04

*DAWES, H. F..Englewood, N. J. '87

*DAWSON, HERBERT W., Mine Supt...................Santa Rita, New Mexico. '03

*DAWSON, T. LAUNCELOT, Min. Engr., Care The Inst. of Min. and Met., Salisbury House, London, E. C., England. '96

*DAY, ARTHUR M................................757 1st St., Salt Lake City, Utah. '03

**DAY, DAVID T., Chief of Division of Mining, U. S. Geological Survey, Washington, D. C. '87

*DAY, WILLIAM H., JR., Mfg. and Min.........................Dubuque, Iowa. '00

**DEAN, A. L., Met., Mt. Lyell Mining and Railway Co., Ltd., Queenstown, Tasmania. '96

*DEAN, GEORGE A., Furnace Supt..Penn. Iron & Coal Co., Canal Dover, Ohio. '86

*DE DEKEN, ALBERT, Met., Min. Engr. and Chem., 64 Rue de la Station, Louvain, Belgium. '84

*DEFTY, WILLIAM E., Min. Engr....................................Phoenix, Ariz. '02

*DEKALB, COURTENAY, Min. Engr., Care Exposed Treasure Mining Co., Mojave, Cal. '92

*DENEUFVILLE, DR. RUDOLPH, 14 Junghofstrasse, Frankfort-a-M., Germany. '02

*DEIDESHEIMER, PHILLIPP, Min. Engr., 2808 Clay St., San Francisco, Cal. '00

**DELANO, FREDERIC A., Genl. Mgr., Chicago, Burlington & Quincy Ry., 209 Adams St., Chicago, Ill. '86

**DELANO, WARREN, JR., Coal Operator........1 Broadway, New York, N. Y. '92
*DE LASHMUTT, IVAN, Prof. of Metallurgy, University of Arizona, Tucson, Ariz. '00
*DEL MAR, ALGERNON, Min. Engr....... ....351 Mary St., Pasadena, Cal. '93
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*DE SAULLES, ARTHUR B., Supt., Bethlehem Works, N. J. Zinc Co. (of Pa.), South Bethlehem, Pa. '71
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*DE SOLLAR, TENNEY C., Min. Engr. and Assayer, Care United Elkhorn Mine, Baker City, Ore. '04
*DETERT, WILLIAM F., Min. Supt...................Jackson, Amador Co., Cal. '99
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*Diggles, Robert N., Cyanide Chem. and Met., Care Lightner Mining Co., Angeles Camp, Cal. '00
*Dikeman, J. M., Cons. Engr.............Rough and Ready, Nevada Co., Cal. '97
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*Dixon, Samuel, Mine Mgr.....................................Macdonald, W. Va. '97
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*Doble, William A., Prest., Abner Doble Co., 200 Fremont St., San Francisco, Cal. '94
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*Don, John R., Chem. and Geol., Waitaki High School, Oamaru, New Zealand. '96
*Donald, William, Assayer and Chem., Care Dr. Lucius Pitkin, 47 Fulton St., New York, N. Y. '00
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†Dorflinger, Charles H., Glass Manfr........................White Mills, Pa. '93
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*Dorman, Edgar S., Supt. and Mgr., Heverin Houle Mining Co., Bearmouth Station, Montana. '02
*Dorr, John Van N., Met. Engr., Care Ludberg, Dorr & Wilson, Terry, So. Dakota. '01
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*Dunham, Lewis A., Cons. Engr.........318 Dwight Bldg., Kansas City, Mo. '99
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*Dunyon, Newton A., Min. Engr...............23 H St., Salt Lake City, Utah. '98
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*Eames, Richard, Jr., Min. Engr..................................Salisbury, N. C. '88

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*Evans, George H., Civ., Min. and Mech. Engr..........Breckenridge, Colo. '98
*Evans, Herbert A., Min. Engr., Care Senor J. M. Restrepo, Honda, Colombia So. America. '94
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*Ferguson, Vincent, Resident Mgr., U. S. Cast Iron Pipe and Foundry Co.,
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*Field, Herbert E., Met....Care Mackintosh-Hemphill Co., Pittsburg, Pa. '03
*Field, Wilfred B., Min Engr., The Carmen Guanajuato Gold Mining Co.,
35 Wall St., New York, N. Y. '02
*Fielding, Charles W., Min. Engr., Blake Hall, Ongar, Essex, England. '99
*Fiero, A. W., Rail Inspector..................1137 The Rookery, Chicago, Ill. '86
*Figari, Alberto, Min. Engr.........Apartado 405, Lima, Peru, So. America. '91
*Filer, Walter G., Vice-Prest. and Genl. Mgr., Twin Falls Land and
Water Co., 221 S. W. Temple St., Salt Lake City, Utah. '99
*Fillmore, Edgerton E., Min. Engr..............................Aspinwall, Pa. '04
*Finch, H. Wynne, Min. Engr., New University Club,
St. James St., S. W., London, England. '98

*FINCH, JOHN W., Min. Engr. and State Geol., Jacobson Bldg., Denver, Colo. '00

*FINDLAY, JAMES, Min. Supt....1285 Pacific St., Vancouver, B. C., Canada. '05

*FINLAY, JAMES RALPH................526 Mesa Road, Colorado Springs, Colo. '95

*FINLEY, WALTER H., Supt., Atpontley Coal Co., Atpontley, Bledso Co., Tenn. '03

†FINNEY, CHARLES E., Prest., General Metals Co., 71 Broadway, New York, N. Y. '97

*FIRMSTONE, FRANK..Easton, Pa. '71

*FIRMSTONE, HARRY, Prest., Longdale Iron Co., Room 522, 608 Chestnut St., Philadelphia, Pa. '75

*FISCHER, LUDWIG F., Mining.........Calle Venero 7, Mexico City, Mexico. '03

*FISHBURN, RANDOLPH E., Min. Engr...............36 Clark St., Chicago, Ill. '00

*FISHER, THOMAS, Genl. Supt., Berwind-White Coal Mining Co., 305 Betz Bldg., Philadelphia, Pa. '89

*FISHER, WILLIAM B., Min. Engr., 201 Kohl Bldg........San Francisco, Cal. '92

*FISK, JAMES H., Min. Engr. and Anal. Chemist, State Mineralogist, 204½ Washington St., Portland, Oregon. '00

*FITCH, FRANK, Cyanide Chem., Black Mountain Min. Co., Magdalena, Sonora, Mexico. '05

**FITCH, MAX B., Supt., Graphic Smelting Works....Socorro, New Mexico. '98

*FITCH, WALTER, Mine Mgr.................................Salt Lake City, Utah. '05

*FITZGERALD, J. MORTON, Care B. Nicoll & Co., 59 and 61 Wall St., New York, N. Y. '01

*FITZGERALD, THOMAS F. M., Mine Supt. of Federal Lead Co.'s Mines, Flat River, Mo. '05

*FITZSIMMONS, FRANCIS J., Engr., Care Field & Co., Cananea, Sonora, Mexico. '98

*FLACK, CHARLES L., Chem., Atha Works, Crucible Steel Co. of America, Harrison, N. J. '90

*FLAGG, STANLEY G., JR., Stanley G. Flagg & Co., 424 N. 19th St., Philadelphia, Pa. '92

*FLAHERTY, ROBERT H., Min. Engr., Supt. of Explorations, Cartier Mining Co., Port Arthur, Ontario, Canada. '93

*FLEMING, EDWARD P., Min. Engr............P. O. Box 354, San Diego, Cal. '02

*FLEMING, HENRY S., Cons. Engr................1 Broadway, New York, N. Y. '03

*FLEMING, JOHN B., Mech. Engr., Care San Francisco Construction Co., Fallon, Nev. '97

*FLEMING, WILLIAM L., Supt., Butte Mine, National Copper Co., Springdale, Wash. '03

*FLESCHHUTZ, JOHN C., Min. and Cons. Engr., The Roderick Dhu Gold Mining Co., Central City, Colo. '03

*FLETCHER, CHARLES R., Min. Engr., 534 Stimson Bldg., Los Angeles, Cal. '85

*FLETCHER, LOUIS K., Met., Care Progreso Mining Co., La Paz, Lower California, Mexico. '05

*FLUKER, WM. H., Min. Engr., Genl. Mgr., Columbia Mining Co., Thomson, Ga. '02

**FLYNN, FRANCIS N., Chem., Fundicion Trojes, Ocampo, Michoacan, Mexico. '98

*FOGH, H. P..Seattle, Wash. '99

**FOHR, FRANZ, Min. Engr. & Met., Room 617, 132 Nassau St., New York, N. Y. '75

*FOHS, F. JULIUS, Geol...Marion, Ky. '04

*FOOTE, ARTHUR B., Asst. Supt., North Star Mines Co...Grass Valley, Cal. '05

*FOOTE, ARTHUR DE W., Civ. Engr., Genl. Mgr., North Star Mines Co., Grass Valley, Cal. '00

*FOOTE, CHARLES H., Late First Vice-Prest. Illinois Steel Co., 4842 Washington Ave., Chicago, Ill. '88

*FOOTE, EMERSON L..........................5833 Bartmer Ave., St. Louis, Mo. '82

*FORBES, DAVID L. H., Min. Engr..................................Clifton, Ariz. '04

**FORBES, DONALD GORDON, Min. Engr. and Met., Shillingstone, Blandford, England. '94

*FORBES, PAUL R., Met., Care J. M. Forbes & Co., 614 Sears Bldg., Boston, Mass. '95

*FORD, EDWARD L., Genl. Mgr., Youngstown Steel Co.....Youngstown, Ohio. '79

*FORD, NILE O. S., Min. Engr......................................Address wanted. '04

*FORDYCE, JOHN R., Vice-Prest. and Genl. Mgr., Thomas Fordyce Mfg. Co., 2115 Broadway, Little Rock, Ark. '92

**FORRESTER, ROBERT, Geol. and Chief Engr., Utah Fuel Co., P. O. Box 1254, Salt Lake City, Utah. '02

†FORSMAN, STANTON W., Care Cal. Gold Mining Co. of Nova Scotia, Melrose, Nova Scotia. '03

*FORSYTH, ALEXANDER, Min. Engr. and Met., The Taylor Park Min. Co., Dorchester, Colo. '97

*FORSYTH, ROBERT, Cons. Engr..................1159 The Rookery, Chicago, Ill. '75

*FORSYTHE, ROBERT J.......1406 Real Estate Trust Bldg., Philadelphia, Pa. '96

*FOSTER, ERNEST LE NEVE, Min. Engr..........47 Bank Block, Denver, Colo. '75

*FOSTER, FLOYD J., Supt., Guggenheim Exploration Co., Villaldama, Nueva Leon, Mexico. '02

†FOSTER GEORGE C., Student....................1723 Tremont St., Denver, Colo. '03

†FOSTER, LEWIS E., Min. Engr................Care C. C. Foster, Mason, Mich. '03

†FOSTER, OSCAR R., Chem..........................910 Ann St., Homestead, Pa. '99

*FOSTER, PHILIP L..........................11 Cornhill, London, E. C., England '96

*FOSTER, RUFUS J., Vice-Prest. International Text Book Co.....Scranton, Pa. '90

*FOUCAR, EDOUARD L., Min. Engr.........Sterns, Roger & Co., Denver, Colo. '85

*FOWLER, EDWARD J., Met.................719 Cole Street, San Francisco, Cal. '00

*FOWLER, SAMUEL S., Cons. Engr., Mgr., London & British Columbia Goldfields, Ltd., etc., Drawer 1024, Nelson, B. C., Canada. '92

*FOX, ALFRED, JR., Genl. Mgr. and Chief Engr. of Mines, Care J. E. Harmsen, Agent to the Caylloma Silver Mining Co., Areguipa, Peru, South America. '05

**FRAMES, MINETT E., Cons. Geol., Box 8, Johannesburg, Transvaal, South Africa. '05

*FRANCIS, GEORGE G., Min. Engr., 12 Cliffords Inn, Fleet St., London, England. '80

*FRANCIS, LEWIS W...............Room 1306, 71 Broadway, New York, N. Y. '89

†FRANCK, ALBERT C., Min. Engr., Care Barstow Mining & Milling Co., Ouray, Colo. '04

*FRANCK, ROBERT P., Engr., La Cia Minera del Picacho, Bacoachi, Sonora, Mexico, via Naco, Ariz. '04

**FRANCKLYN, CHARLES G., Vice-Prest., Central Union Gas Co., 350 Alexander Ave., New York, N. Y. '80

*FRANK, ALFRED, Civ. and Min. Engr., Montana Ore Purchasing Co., Butte, Mont. '03

*FRANK, HARRY L., Min. Engr....................625 16th Ave., Denver, Colo. '03

*FRANKE, EMIL A., Min. Engr...............519 Cleveland Ave., Chicago, Ill. '02
*FRASCH, H., Oil Refiner........................681 Euclid Ave., Cleveland, Ohio. '93
*FRASER, ALEXANDER, Met., Great Boulder Mine, Boulder, Western Australia. '04
**FRASER, JOHN H., Min. Engr., Care South American Development Co., Apartado 336, Guayaquil, Ecuador, South America. '04
*FRASER, J. DIX, Asst. Director of Works, Dominion Iron & Steel Co., Sydney, Cape Breton, Nova Scotia. '94
**FRAZER, DR. PERSIFOR, Geol. & Chem., 1042 Drexel Bldg., Philadelphia, Pa. '71
*FRAZIER, WILLIAM T.......................3221 Ellis St., South Berkeley, Cal. '03
*FRECHEVILLE, ROBERT J., Min. and Cons. Engr., 7 Lothbury, London, E. C., England. '84
**FRECHEVILLE, WILLIAM, Min. Engr., 35 Queen Victoria St., London, E. C., England. '84
*FREELAND, FRANCIS T., Min. and Mech. Engr., University Club, Denver, Colo. '85
*FREELAND, WILLIAM H., Genl. Mgr., D. S. Coal & Iron Co., Isabella, Tenn. '01
*FREEMAN, AMBROSE W., Min. Engr., Falmouth Chambers, 117 Pitt St., Sydney, New South Wales, Australia. '05
*FREEMAN, STANTON S., Supt. of Furnaces, Carbon Iron & Steel Co., Parryville, Pa. '01
*FREMERSDORF, WILLIAM F., Min. Engr. and Met., 933 Ninth St., San Diego, Cal. '05
*FREYMOUTH, WILLIAM A., Mine Mgr., Genl. Mgr., The Burma Mines Development & Agency, Ltd., West Moat Road, Mandalay, Burma, India. '05
*FRICK, H. C., Coke Mnfr..........................Carnegie Bldg., Pittsburg, Pa. '79
*FRICKE, F. G., Analytical and Cons. Chemist...Bissell Block, Pittsburg, Pa. '79
*FRICKE, JOHN H., Mining..Bisbee, Ariz. '88
*FRITZ, JOHN...Bethlehem, Pa. '72
*FROEHLING, HENRY, Chem. and Min. Engr., 17 S. Twelfth Street, Richmond, Va. '90
*FROSSARD, JOHN D., Cons. and Min. Engr...Orthez, Basses-Pyrenees, France. '85
*FUCHS, FERNANDO C., Min. Engr., Sociedad de Ingenieros, Apartado 981, Lima, Peru, So. America. '02
*FUENTE, JESUS DE LA, Surveyor, Member of State Congress, Nadadores, Coahuila, Mexico. '02
*FULLER, CHARLES D., Chemist..Latrobe, Pa. '05
*FULLER, EDWARD L., Prest., International Salt Co..............Scranton, Pa. '04
*FULLER, FREDERICK D., Genl. Mgr., Oregon Smelting & Refining Co., Sumpter, Oregon. '04
*FULLER, JAMES W., Genl. Mgr., McKee, Fuller & Co. Car Wheel and Axle Wks., Catasauqua, Pa. '94
*FULLER, JAMES W., JR., Secy. and Treas., Lehigh Car Wheel and Axle Co., Catasauqua, Pa. '94
*FULTON, CHARLES H., Prof. of Min. and Met., South Dakota State School of Mines, Rapid City, So. Dak. '03
*FULTON, JOHN, Min. Engr......................136 Park Place, Johnstown, Pa. '72
*FULTON, THOMAS T., Met., The Dominion Antimony Co., Ltd., West Gore, Nova Scotia. '05
*FURNESS, DWIGHT, Merchant and Miner, The Dwight Furness Co., Guanajuato, Mexico. '02

*Furness, James W., Assayer and Chem.,
460 Bullitt Bldg., Philadelphia, Pa. '00
*Fusz, Paul A., Mining........................422 Security Bldg., St. Louis, Mo. '79

*Gage, Edward C., Min. Engr.,
Huahuapan Mining Co., San Demas, Durango, Mexico. '05
**Gage, Eliphalet B., Prest., Congress Gold Co. and Tombstone Cons.
Mines Co., Ltd., Tombstone, Ariz. '99
*Gage, Robert B., Chem. and Min. Engr..........................Titusville, Pa. '04
†Gaines, Ambrose P..........................119 N. Spruce St., Nashville, Tenn. '88
*Gallagher, James B., Mgr., Colo. Smelting & Mining Co....Butte, Mont. '00
*Gallway, Harry A., Gen. Mgr., Parrot Silver & Copper Co..Butte, Mont. '05
*Garcia, Esteban, Mine Mgr...P. O. Box 20, Parral, Chihuahua, Mexico. '05
*Garcia, John A., Min. Engr., Chief Engr.,
Deering Coal Co., Old Colony Bldg., Chicago, Ill. '05
*Garcia, Telesforo, Engineering, Sta. Teresa 2, Apartado 463,
Mexico City, Mexico. '02
*Garfield, Alexander S.,
67 Avenue de Malakoff, 16e Arrono, Paris, France. '05
*Garfield, Charles D...............................P. O. Box 293, Nome, Alaska. '02
*Garlichs, Herman, Supt. and Met., Lead Dept., Perth Amboy Plant,
American Smelting & Refining Co., Maurer, N. J. '89
*Garretson, Oliver S., Prest., Garretson Southern Furnace Co.,
790 Ellicott Sq., Buffalo, N. Y. '98
*Garrett, William W., Met..Rolla, Mo. '03
*Garrey, George H., Min. Geol.,
Room 331, U. S. Geological Survey, Washington, D. C. '05
*Garrison, F. Lynwood, Min. and Civ. Engr.,
726 Drexel Bldg., Philadelphia, Pa. '83
*Garthwaite, E. H., Resident Min. Engr., British South Africa Co.,
Box 186, Bulawayo, Rhodesia, So. Africa. '82
*Garvin, Charles J., Min. Engr......1761 Washington Ave., Denver, Colo. '03
*Garvin, John M., Furnace Mgr. Brass Fdy. & Mach. Co., Rock Run, Ala. '92
†Gary, Elbert H., United States Steel Corporation,
71 Broadway, New York, N. Y. '04
*Garza-Aldape, J. M., Min. Engr.................Torreon, Coahuila, Mexico. '05
*Gatch, Elias S., Mining and Smelting, Genl. Mgr.,
Granby Mining & Smelting Co., St. Louis, Mo. '04
†Gates, J. W., Min. and Mech. Engr., Mine and Smelter Supply Co.,
17th and Blake Sts., Denver, Colo. '03
*Gatzmer, William C., Civ. and Mech. Engr.....Tacony, Philadelphia, Pa. '88
*Gaujot, Claude L., Civ. and Min. Engr., Ohio & Big Sandy Coal Co.,
Williamson, W. Va. '00
*Gay, Ware B., Mayo Land and Bridge Co.......................Richmond, Va. '95
*Gayhart, Walter C., Min. Engr., Met. and Atty. at Law,
209 Huron St., Toledo, Ohio. '00
*Gayley, James, 1st Vice-Prest., United States Steel Corporation,
71 Broadway, New York, N. Y. '80
*Gaylord, Frank B., Blast Furnace Mgr., Deseronto Iron Co., Ltd.,
Deseronto, Ont., Canada. '00
**Gazzam, Joseph P., Min. Engr., Genl. Mgr., Simmer & Jack Proprietary
Mines, Ltd., P. O. Box 192, Germiston, Transvaal, So. Africa. '84

*Gee, Emerson, Cons. Engr..................534 So. Hill St., Los Angeles, Cal. '03
*Geisendorfer, Henry A., Min. Engr., Lassen Mining Co., Hayden Hill, Lassen Co., Cal. '03
**Gemmell, Robert C., Civ. and Min. Engr., Guggenheim Exploration Co., Bonanza y Anexas Mines, Bonanza, Zacatecas, Mexico. '03
*Gender, Harry W. C.....................2820½ Bush St,, San Francisco, Cal. '04
**Gennes, A. A. de, Cons. Min. and Civ. Engr., 25 Rue Raffet, Paris, XVI^e, France. '02
*Geoghen, Robert H., Min. Engr., Minas de Rio Tinto, Provincia de Huelva, South Spain. '05
*George, Harold C., Min. Engr., Instructor, 1916 Perrysville Ave., Allegheny, Pa. '05
*George, R. D., Prof. of Geology, University of Colorado.....Boulder, Colo. '02
*Geppert, Richard M., Min. Engr................................Tonopah, Nev. '02
*Gerhauser, William, Secy., Superior Charcoal Iron Co., 614 Majestic Bldg., Detroit, Mich. '88
*Germann, Franz....................................La Paz, Bolivia, So. America. '00
*Gibb, Allan, Miner and Met., Genl. Mgr., O. K. Copper Mines Syndicate, Mungana, Chillagoe, via Queensland, Australia. '00
*Gibson, Charles H., Min. Engr., Supt. Mines and Mills, Peregina Min. & Mil. Co., Apartado No. 59, Guanajuato, Mexico. '82
*Gibson, Robert, Mine Mgr., Care C. W. Cropper, Kalgoorlie, Western Australia. '92
*Gibson, Thomas W., Dir............Bureau of Mines, Toronto, Ont., Canada. '01
*Gifford, Alvah W., Miner., Secy., International Miners' Association, Box 12, El Paso, Texas. '04
*Gifford, Stanley, Treas. & Eastern Mgr., Montana Ore Purchasing Co., United Copper Co., 31 Nassau St., New York, N. Y. '95
**Gilbert, G. K., Geol........... U. S. Geological Survey, Washington, D. C. '92
*Gilchrist, John D., Supt., Iron Mines, Colorado Fuel & Iron Co., Main Office, Denver, Colo. '96
**Gilchrist, Percy C., Met., Frognal Bank, Finchly Road, N.W., London, England. '91
*Gilkerson, Harvey G., Min. and Civ. Engr.................Telluride, Colo. '04
†Gillespie, T. A................Empire Bldg., 71 Broadway, New York, N. Y. '86
†Gillet, Lorenzo M., Treas. and Secy., Hormiguero Central Co., 69 Wall St., New York, N. Y. '93
*Gillette, H. P., Editor, _Engineering News_..St. Paul Bldg., New York, N. Y. '03
*Gillie, John, Min. Engr., Anaconda Copper Mining Co........Butte, Mont. '87
*Gilpin, Francis, Mine Mgr., Care Wm. A. Otis & Co., Bankers, Colorado Springs, Colo. '99
*Ginder, William H. H..Pottsville, Pa. '00
*Gipps, Frederick deV., Min. Engr., Genl. Mgr., Stannary Hills Mines & Tramway Co., Ltd, Stannary Hills, North Queensland, Australia. '94
*Girault, Edmond, Min. Engr., Genl. Mgr., Negociacion Minera de San Rafael y Anexas, Pachuca, Mexico. '98
*Giroux, Joseph L..............2045 West Washington St., Los Angeles, Cal. '02
*Glassbrook, Clarence I., Mine & Mill Supt., Freeman-Smith Lumber Co., Millville, Ark. '02
*Gleim, Fritz, Director of Furnaces,.........Portoferraio, Isle of Elba, Italy. '92
**Glenn, Leonidas C., Prof., Geology, Vanderbilt University, Nashville, Tenn. '00

*GLENN, WILLIAM, Mgr., Baltimore Chrome Works,
1348 Block St., Baltimore, Md. '81
*GLENN, WILMER D., Min. Engr............601 North Pearl St., Joplin, Mo. '04
*GLOBE, H. GORDON, Min. Engr.,
Care Humboldt Min. & Reduction Co., Nogales, Ariz. '03
*GMELIN, ERNEST, Cons. Min. Engr..........Apartado 43, Zacatecas, Mexico. '98
*GODDARD, SYDNEY F., Min. Engr., Manor House, Bulcote,
Nottinghamshire, England. '98
*GODFREY, ELI SANDFORD, Min. and Mech. Engr.,
117 Midwood St., Brooklyn, N. Y. '93
*GODFREY, JOHN R., Genl. Mgr., Broken Hill Proprietary Block 14 Co.,
Ltd., Broken Hill, New South Wales, Australia. '97
†GODLEY, GEORGE McM., Engr...........101 West 80th St., New York, N. Y. '98
*GODSHALL, HARVEY H., Chem. and Min. Engr., Moselem Mining Co.,
Haas Bldg., Allentown, Pa. '00
*GODSHALL, L. D., Min. Engr. and Met., North American Exploration Co.,
501 Equitable Bldg., Denver, Colo. '94
†GOLDMAN, MARCUS I., Student of Min. Engineering, Care J. Goldman,
68 William St., New York, N. Y. '03
*GOMEZ, PERFECTO, Min. Engr........................Quimichis, Tepic, Mexico. '99
*GOOD, GEORGE McC. H., Engr. of Mines......................Osceola Mills, Pa. '87
*GOODALE, CHARLES W., Min. Engr., Mgr., Boston & Montana Con.
Copper & Silver Mining Co., Butte, Mont. '76
*GOODALE, STEPHEN L., Min. Engr............Camp Bird Mills, Ouray, Colo. '04
*GOODLOE, MEADE, Asst. Supt., Congress Cons. Mining Co., Ltd.,
Congress, Ariz. '96
**GOODRICH, R. R., Elec. Engr.............Care L. A. Clark, Westfield, N. J. '88
*GOODSPEED, WM. A..Nelsonville, Ohio. '02
*GÖRANSSON, KARL F., Met.................................. .Sandviken, Sweden. '01
*GORDER, WALTER J., Met..Erie, Colo. '03
*GORDON ERNEST, Min. Engr.............Apartado 157, Guadalajara, Mexico. '05
*GORDON, HENRY A., Civil and Min. Engr., Box 541, Auckland, New Zealand. '87
*GORDON, JOHN, Miner and Merchant..22 So. Audley St., London, England. '00
*GORDON, ROBERT W., Chem...Rhyolite, Nev. '05
**GORDON, WILLIAM D., Mining Machinery, P. O. Box 1185,
Johannesburg, Transvaal, So. Africa. '96
*GORE, THOMAS S., Land Surveyor.......................Victoria, B. C., Canada. '05
*GORMLY, SAMUEL J., Smelter Supt.,
Care Bingham Copper and Gold Mining Co., West Jordan, Utah. '00
*GOSS, EDWARD O., Asst. Treas...........Scovill Mnfg. Co., Waterbury, Conn. '94
*GOTTSBERGER, B. BRITTON, Min. Engr., Care Tennessee Copper Co.,
Copperhill, Tenn. '01
*GOULD, CHARLES J., Assayer and Surveyor.................. ....Address wanted. '99
*GOULD, CHARLES NEWTON, Prof. of Geol., University of Oklahoma,
Norman, Okla. Ty. '02
*GOULD, HUBERT J., Min. Engr. and Met., Asst. Engr.,
Great Cobar Copper Mine, Cobar, New So. Wales, Australia. '04
Goupilliere, Prof. Haton de la, Inspecteur Général des Mines,
7 Passage Bonado, Pau, Basses, Pyréneés, France.
*GOUYARD, GUSTAVE M., Met.......................1620 Clarkson St., Denver, Colo. '96
*GOW, P. GEORGE, Min. Mgr.................Bohemian Club, San Francisco, Cal. '99

*GRABILL, CLARENCE A., Smelter Supt.....Shannon Copper Co., Clifton, Ariz. '03
**GRACE, WILLIAM F., Min. and Met. Engr., Pine Creek Gold Mines Port Darwin, North Australia. '95
*GRACEY, ARTHUR H., Min. Mgr..........................Nelson, B. C., Canada. '05
*GRAHAM, KENNETH M., Mill Mgr., "The Lodge," Hamilton, Waikato, New Zealand. '03
*GRAHAM, WALTER, Coal and Coke, 609–612 Harrison Bldg., 15th and Market Sts., Philadelphia, Pa. '00
*GRAHAM, WILLIAM W., Mining.........British Club, Mexico City, Mexico. '05
*GRAMMER, F. LOUIS..........................2422 Madison Ave., Baltimore, Md. '92
**GRAMMER, WILLIAM S., Min. Engr., Supt., Wabana Mine, Dominion Iron and Steel Co., Bell Island, Newfoundland. '03
**GRANGER, ARTHUR O...........707 and 709 Bailey Bldg., Philadelphia, Pa. '91
*GRANGER, HENRY G., Min. Engr....Quibdo, Choco, Colombia, So. America. '95
*GRANNIS, URI B., Millman.........................University Club, Chicago, Ill. '03
*GRANSTEDT, FRANK H., Supt., Victorian Deep Leads, Ltd., Baringhup, Victoria, Australia. '04
*GRÄNSTROM, GUSTAF A., Min. Engr.......................Karrgrufven, Sweden. '98
*GRANT, GEO. H., Geol. and Min. Engr., Care Capt. Wm. Grant, Point Ellice, Victoria, B. C., Canada. '01
*GRANT, JAMES B.......................................777 Pearl St., Denver, Colo. '89
*GRANT, ROBERT J., Min. Engr., 815 Ernest and Cranmer Bldg., Denver, Colo. '99
*GRANT, ULYSSES S., Prof., Geology, Northwestern University, Evanston, Ill. '01
*GRASSELLI, C. A.........................Grasselli Chemical Co., Cleveland, Ohio. '92
*GRAVE, ERNEST, United States Mining Co., Minas Nuevas, Parral, Chihuahua, Mexico. '98
*GRAVE, PERCY, Min. Engr., Supt., Lead Mines, Mazapil Copper Co., Ltd., Concepcion del Oro, Zacatecas, Mexico. '98
*GRAVES, FAYETTE P., Supt. Mines and Secy., Doe Run Lead Co., Doe Run, Mo. '92
*GRAVES, McDOWELL, Min. Engr., Mgr., Mexican Branch, Douglas, Lacey & Co., Zuleta No. 18, Mexico City, Mexico. '02
*GRAY, EDWIN F., Supt., Nevada Consoldidated Copper Co......Ruth, Nev. '04
*GRAYSON, LAURENCE W., Cons. Min. Engr. & Met., Ludstone Chambers, 352 Collins St., Melbourne, Victoria, Australia. '00
*GREEN, ANDREW H., JR., Mgr.....The Solvay Process Co., Detroit, Mich. '03
*GREEN, CHARLES B., Chem..............................79 N. 4th St., Easton, Pa. '87
*GREENAMYER, ARTHUR G., Chem., Tennessee Coal, Iron & R.R. Co., Oxmoor, Ala. '02
*GREENARD, WILLIAM F., Inspector of Mines, Menzies, North Coolgardie, Western Australia. '03
*GREENE, FRANCIS V., The Niagara Construction Co., Ltd., Elliott Square, Buffalo, N. Y. '88
*GREENE, FRED. T., Min. Engr., Asst. Geol., Anaconda Copper Mining Co., Butte, Mont. '99
*GREENE, LEWIS H., Min. Engr., *Los Angeles Mining Review*, Los Angeles, Cal. '05
*GREENIDGE, SAMUEL M...Edwardsville, Ill. '03
*GREENLEY, LOUIS A., Min. Engr......204½ Washington St., Portland, Ore. '05
*GREENWAY, THOMAS J., Min. and Met. Engr., Genl. Mgr., New Chillagoe Railway & Mines, Ltd., Chillagoe, No. Queensland, Australia. '95

**Greer, Herbert C., Min. Engr., Mgr., Coal and Coke Dept.,
La Bell Iron Works, Steubenville, O. '03
*Gregson, William Hilder, Mining and Metallurgy,
Asst. Underground Mgr., The Proprietary Co.,
Broken Hill, New South Wales, Australia. '02
*Grey, George R., Civ. and Min. Engr., P. O. Box 777, Johannesburg,
Transvaal, So. Africa. '89
*Grider, Richard L., Hydraulic Engr.......................Serad Valley, Cal. '04
*Grier, Thomas J., Supt...........Homestake Mining Co., Lead, So. Dakota. '92
*Griffin, Frank W., Prest., Western Engineering and Construction Co.,
408–414 Rialto Bldg., San Francisco, Cal. '02
**Griffin, H. M., Mine Owner, Care Windham Club, St. James Square,
London, S. W., England. '04
*Griffin, Martin L., Chem.,
Care West Virginia Pulp & Paper Co., Mechanicsville, N. Y. '89
*Griffin, Maurice Edward, Secy., West. Engineering and Construction Co.,
408–414 Rialto Bldg., San Francisco, Cal. '02
*Griffin, P. H., Prest..................N. Y. Car Wheel Works, Buffalo, N. Y. '91
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*Luce, Wilson A., Vice-Prest., Lake Erie Gas, Coal & Coke Co., 617 Ferguson Bldg., Pittsburg, Pa. '03
*Lucy, Frank A., Min. Engr...Goldfield, Nev. '03
*Ludlow, Edwin, Min. Engr. & Genl. Mgr., Mexican Coal and Coke Co., Las Esperanzas, Coahuila, Mexico. '93
*Ludlow, Lionel............Standard Bank, Bulawayo, Rhodesia, So. Africa. '01
*Ludwig, Carl P., Cons. Min. Engr......320 First Ave., Birmingham, Ala. '04
*Lukens, Jawood, Prest., Longmead Iron Co., Conshohocken, Pa., and 434 Drexel Bldg., Philadelphia, Pa. '84
*Lukis, Ernest du B., Cons. Min. Engr., Apartado 2543, Mexico City, Mexico. '01
*Lund, Iens, 20 Cothleigh Road, West Hampstead, London, N. W., England. '03
*Lundberg, John, Min. Supt., Lundberg, Dorr & Wilson, Deadwood, So. Dak. '93
*Lundbohm, Hjalmar, Genl. Mgr., Luossavaara-Kürunavaara Co., Kiruna, Sweden. '92
**Lunt, Horace F., Min. Engr., Mgr., Golden Cloud Mining Co., York, Mont. '03
*Lustosa, Joaquim de Almeida, Civ. and Min. Engr., "Morro de Mina," Manganese Mining Co., Lafayette-Minas Geraes, Brasil, South America. '05
*Luther, E. C., Min. Engr...Pottsville, Pa. '05
*Lydecker, Irving S., Min. Engr., Care John V. Le Moyne, Isham, Tenn. '98
*Lyle, David Alexander, Lieut. Colonel, Ordnance Dept., U. S. Army, Augusta, Ga. '88
**Lyman, Benjamin S., Min. Engr...........708 Locust St., Philadelphia, Pa. '71
††Lyman, Frank, Treas., Low Moor Iron Co. of Virginia, Tontine Bldg., 88 Wall St., New York, N. Y. '77
*Lyman, Robert, Jr., Min. Engr., Care Illinois Central RR. Co., Stuyvesant Docks, New Orleans, La. '00
*Lyman, Robert H............ ....Holden, W. Va. '96
*Lysle, Walter Scott, Secy., *Mining and Metallurgical Engineer*, Met. Engr., Auburn Ball Bearing Co., 29 Elizabeth St., Rochester, N. Y. '02
*McAllister, J. Edgar, Smelter Manager, British Columbia Copper Co.'s Smelter, Greenwood, B. C., Canada. '05
*McArthur, Robert A., Min. Engr., Parrott Silver & Copper Co., 320 Dakota St., Butte, Mont. '00
*McCaffery, Richard S., Min. Engr., 316 East 124th St., New York, N. Y. '95
†McCallum, A. Campbell, Min. Engr.................Victoria, B. C., Canada. '02
†McCallum, William H., Mech. Engr., 6602 Germantown Ave., Philadelphia, Pa. '84
*McCan, E. K., Care Braden Copper Co., Graneros, Chili, South America. '03

*McCann, Ferdinand, Min. Engr. and Met., Assayer and Chem.,
1a Independencia, No. 36, Mexico City, Mexico. '02
*McCarthy, Edward E., Min. Engr..........43 Irving St., Cambridge, Mass. '00
*McCarthy, Edward T., Cons. Min. Engr.,
10–11 Austin Friars, London, E. C., England. '97
*McCarthy, M. E., Min. Engr......1025 South 19th St., Birmingham, Ala. '97
*McCarty, Edward P., Instructor in Mining, Minnesota School of Mines,
Minneapolis, Minn. '03
*McCarty, Geo. J., Mine Mgr............................Torres, Sonora, Mexico. '01
*McCaskell, Jasper A., Min. Engr., The Daly-West Mining Co.,
Park City, Utah. '04
*McCaskey, Dr. Hiram D., Chief of Mining Bureau, Box 449,
Manila, Philippine Islands. '05
*McCaustland, Elmer J., Asst. Prof. of Civ. Engineering,
105 Valentine Place, Ithaca, N. Y. '03
*McCay, Dr. Le Roy W., Prof. of Inorganic Chemistry,
Princeton University, Princeton, N. J. '85
*McChesney, W. S., Prest., Terminal Association of St. Louis, St. Louis, Mo. '04
*McChrystal, J. C., Genl. Supt., Godiva and Gemini Mining Cos.,
P. O. Box "F," Eureka, Utah. '01
*McChrystal, John Henry, Mine Supt........................Sunnyvale, Cal. '03
*McClave, James M., Met. Engr., Supt., The Western Ore Separating Co.,
145 Keith Block, Salt Lake City, Utah. '05
*McCleary, William B., Mine Mgr..................................Tucson, Ariz. '03
*McClelland, James F..........................P. O. Box 852, Tonopah, Nev. '03
*McClintock, Saxe M., Assayer and Chem.......................Burton, Wash. '03
*McClintock, William H., Genl. Mgr., Don Pedro Gold Mine,
Crocker Bldg., San Francisco, Cal. '98
*McClure, David, Mine Supt...................Gwinmine, Calaveras Co., Cal. '00
*McClure, Samuel, Genl. Mgr., Stewart Iron Co., Ltd.,
Sharon, Mercer Co., Pa. '91
*McClurg, James A., Min. Engr................Majestic Bldg., Denver, Colo. '98
*McConnell, John, Min. Engr..........51 Roslea Drive, Glasgow, Scotland. '03
*McConnell, John...Munhall, Pa. '96
*McConnell, Niven, Supt., Furnaces and Steel Works,
Carnegie Steel Co., Donora, Pa. '94
*McCord, William H., Min. and Met. Engr., Genl. Mgr., Wm. H.
McCord & Co., Apartado 57, Guanajuato, Mexico. '99
*McCormack, G. B., Vice-Prest., Lookout Mountain Iron Co., etc.,
Birmingham, Ala. '91
*McCormick, Edward, Supt., Bertha Gold Placer Co. of
Colombia, S. A., 1564 Hecla St., Calumet, Mich. '97
*McCormick, Henry, Jr............Central Iron & Steel Co., Harrisburg, Pa. '92
*McCormick, Vance C., Mayor................223 Market St., Harrisburg, Pa. '94
*McCoy, James W., President New Century Exploration and Invest. Co.,
500–125 La Salle St., Chicago, Ill. '97
*McCreath, Andrew S., Chem................223 Market St., Harrisburg, Pa. '75
*McCreath, Lesley, Chem.....................223 Market St., Harrisburg, Pa. '02
*McCree, Parrington M., Mine Supt........Box 1027, Salt Lake City, Utah. '99
*McCrery, Charles, Vice-Prest., Tennessee Coal, Iron & R. R. Co.,
Birmingham, Ala. '89
*McCulloch, Richard.............Care St. Louis Transit Co., St. Louis, Mo. '91

*McCullough, Edmund H., Prest., Westmoreland Coal Co., 224 So. 3d St., Philadelphia, Pa. '01
*McCurdy, John E..........Care F. C. Oaxaca, y Oriente, Oaxaca, Mexico. '97
*McDaniel, Alex. K., Min. Engr., Supt., The Copper Queen Mining & Smelting Co., Grant, Mont. '02
*McDermott, Walter, Min. and Met. Engr., 3 London Walls Bldg., London, E. C., England. '74
*McDonald, Jno. A., Civ., Min. and Cons. Engr., Care McDonald, Searles & Co., 4 Chapel St., Cripplegate, London, E. C., England. '01
*McDonald, Joseph A., Asst. Genl. Supt., Ohio Steel Works & Furnaces, Carnegie Steel Co., Youngstown, Ohio. '00
*McDonald, Samuel, Genl. Supt., Tenn. Coal and Iron Co....Ensley, Ala. '85
*McDonald, Thomas, Genl. Supt., Ohio Works and Furnaces and Niles Furnace, Carnegie Steel Co., Youngstown, Ohio. '90
*McDowell, J. C., Vice-Prest. and Genl. Mgr., Union Natural Gas Corporation, 1206 Farmers' Bank Bldg., Pittsburg, Pa. '94
†McElvenny, Robert F., Chemist, Tacoma Smelter, Tacoma, Washington. '03
*McEwen, Samuel, Met. Engr............................Box 945, Denver, Colo. '05
*McGee, John, Min. Engr.......................................Kendall, Mont. '05
*McGrath, John, Mine Mgr.............Apartado 121, Mexico City, Mexico. '02
*McGregor, J. Murray, Min. Engr, 3 Minanciho, Ushigome, Tokio, Japan. '01
*McGrew, Edward, Civ. and Min. Engr....431 Fourth Ave., Pittsburg Pa. '05
*McIlvain, Edward M., Prest., Bethlehem Steel Co., South Bethlehem, Pa. '86
†McIlvain, J. Gibson, Lumber Merchant, 58th St. and Woodland Ave., Philadelphia, Pa. '01
*McIlvain, William R., Prest., Reading Gas. Co.................Reading, Pa. '92
*McKaig, John S..........................300 South Linden Ave., Pittsburg, Pa. '04
*McKay, Hood, Mine Supt., Lykens Valley Coal Co., etc........Lykens, Pa. '03
*McKee, John A..........................2962 Richmond St., Philadelphia, Pa. '02
*McKee, John F., Mine Supt......................Baker Mines, Carroll Co., Va. '92
*McKenna, Alexander G., Met., Chemist, Firth Sterling Steel Co., Demmler, Pa. '96
*McKenna, Charles F., Anal. and Cons. Chem., 221 Pearl St., New York, N. Y. '94
**McKillop, John, College Secy., University Hall, Clare Market, London, W. C., England. '93
*McKinlay, William B., Min. Engr., Care Newhouse Mines & Smelter Co., Newhouse, Beaver County, Utah. '02
†McKinney, R. C., Prest., Niles-Bement-Pond Co., 111 Broadway, New York, N. Y. '86
*McLanahan, J. King, Iron Mfr. and Miner................Hollidaysburg, Pa. '81
*McLanahan, John King, Jr., Secy., American Lime & Stone Co., Hollidaysburg, Pa. '04
*McLaughlin, Harold M., Min. Engr., Care Dolores Mining Co., Teniosachic, Chihuahua, Mexico. '04
*McLean, John H...Genl. Supt., Oliver Iron Mining Co., Ironwood, Mich. '00
*McLeavy, John, Mine Mgr.......John McLeavy & Co., Punxsutawney, Pa. '75
*McLennan, J. S.......Dominion Coal Co., Ltd., 95 Milk St., Boston, Mass. '85
*McLintock, Archibald, Surveyor and Engr., Care Cia Minera de Penoles, Ojuela, Durango, Mexico. '03
*McLure, Charles D., Min. Engr.........608 Security Bldg., St. Louis, Mo. '88
†McMahan, Charles H., Care American Smelting & Refining Co., Asientos, Aguascalientes, Mexico. '95

*McMurray, Max..........................Perry Payne Bldg., Cleveland, Ohio. '02

*McNaugher, David W., Civil Engr., Robert W. Hunt & Co., Monongahela Bank Bldg., Pittsburg, Pa. '96

*McNaughton, George W., Mine Mgr., General Electric Co.'s Mica Mines, Sydenham, Ontario, Canada. '04

*McNeill, Harry T., Cyanide Chem.......................Sheboygan, Wis. '03

*McNulty, Samuel G., Vice.-Prest. and Genl. Mgr., The Thacker Coal Min. Co., Thacker, W. Va. '02

*McVichie, D......................700 McCornick Bldg., Salt Lake City, Utah. '91

*MacArthur, John S., Min. Engr. and Met., 6 Broad St. Place, London, E. C., England. '92

*Maccallum, N. E., Supt., Steel Plant, Phœnix Iron Co., Phœnixville, Pa. '02

*Macco, Heinrich, Civ. and Met. Engr.........................Siegen, Germany. '92

*MacDonald, Bernard.......................Apartado 23, Guanajuato, Mexico. '89

*Macdonald, Charles, Civ. Engr.............2 Wall Street, New York, N. Y. '75

*MacDonald, Jesse J., Min. Engr., Genl. Mgr., Mendoza Consolidated Copper Mining Co., Triunfo, Lower California, Mexico (via Nogales, Ariz). '00

*Macdonald, Joseph, Mine Mgr., Alaska Treadwell Gold Mining Co., Douglas Island, Alaska. '96

*MacDonald, Michael E., Mine Manager, Guanajuato Consolidated Mining & Milling Co., etc., Guanajuato, Mexico. '02

*MacDonald, William T., Min. Engr., 301 Livingston Hall, Amsterdam Ave. and 115th St., New York, N. Y. '01

*Macdougal, Charles W., Min. Engr., Care Quincy Mining Co., Hancock, Mich. '04

*Macfarlane, Graham, Prest., Red River Iron Co., 53 American National Bank Bldg., Louisville, Ky. '86

*MacFarlane, Rienzo W., Mgr., Cherokee (Mexican) Prop. Co., Parral, Chihuahua, Mexico. '02

*Macgeorge, Alexander J., Min. Investor..Kalgoorlie, Western Australia. '97

*Machalske, Dr. Florentine J., Research Chem., P. O. Box 25, Station "W," Brooklyn, N. Y. '03

*Mackay, Angus, Min. and Milling, La Rica Consolidated, Blewett, Wash. '87

*Mackay, Angus R., Chem...................................Parsons, New Mexico. '96

*Mackay, Philip A., Mgr., Acid and Phosphate Depts., Mt. Lyell Mining & Refining Co., 39 Queen St., Melbourne, Victoria, Australia. '99

*Mackay, Walter, Mining.........Mammouth Mining Co., Wallace, Idaho. '87

*Mackenzie, G. S., Met., Sydney Tin Smelting Co., Woolwich, New South Wales, Australia. '87

*Mackenzie, Louis, Mech. Engr., La Belle Iron Works..Steubenville, Ohio. '96

*Mackey, Perry D................ Care National Tube Co., Wheeling, W. Va. '94

*MacKinnon, G. W. W., Care George Duncan & Co., 2 East India Ave., Leadenhall St., London, E. C., England. '93

*Maclennan, Frank W., Min. Engr.......................................Ely, Nev. '04

*MacLeod, Wm. Alex., Mine Mgr., Brillient Extender Gold Mining Co., Charters Towers, Queensland, Australia. '01

*MacNaughton, James, Prest. & Treas., MacIntyre Iron Co., 26 Cortlandt St., New York, N. Y. '93

*MacNaughton, James, Min. Engr., Genl. Mgr., Calumet & Hecla Mines, Calumet, Mich. '90

**MacNeill, Charles M., Vice-Prest. and Genl. Mgr., U. S. Reduction & Refining Co., etc., Colorado Springs, Colo. '99

*Macnutt, Charles H., Min. Engr., Genl. Mgr., Societé des Mines de Cuiore de Catemou Co., Cassilla 1000, Valparaiso, Chili, So. America. '90

*Macomb, John de N., Jr..................1407 Kentucky St., Lawrence, Kan. '00

*MacPherran, Ralph S., Chem........Allis-Chalmers Co., Milwaukee, Wis. '97

*Maffett, Robert R., Met., Supt., Orford Copper Co.........Bayonne, N. J. '05

*Magenau, William, Cyanide Met...........Box 232, Deming, New Mexico. '02

*Magnuson, Mark G., Asst. Supt., Anita Copper Mines Co., S. A., Cocoeit, Sonora, Mexico. '05

*Magruder, William T., Prof. of Mech. Engineering, Ohio State University, Columbus, Ohio. '88

*Main, Alfred F., Asst. Genl. Mgr., El Oro Mining & Railway Co., Ltd., El Oro, Mexico, Mexico. '02

*Mainwaring, Hugh M. C., Min. Surveyor, Care Chillagoe Railway & Mines, Ltd., Chillagoe, Queensland, Australia. '99

*Maitland, George C., Min. Engr., Care Union Bank of Australia, 71 Cornhill, London, E. C., England. '00

*Maiz, Joaquin, Banker and Merchant, Zuazua No. 5, Monterey, Nueva Leon, Mexico. '03

*Makita, Tamaki, Min. Mgr., Chief Engr. to Müke Coal Mines, Mitsui Mining Co., Tokio, Japan. '00

*Malcolmson, James W., Cons. Engr., Mills Bldg., or P. O. Box 327, El Paso, Texas. '90

*Malins, Francis A., Min. Engr.....................429 16th St., Denver, Colo. '97

*Malm, J. Lawrence...Corbin, Mont. '96

*Mandell, Frank C., Min. Engr...................................Hailey, Idaho. '05

*Manley, Frank Austin, Chief Engr., Union Pacific Coal Co., Box 194, Rock Springs, Wyo. '02

*Manley, Henry L., Min. Engr., Crows' Nest Pass. Coal Co., Fernie, B. C., Canada. '93

*Mann, James S., Assayer and Chem., University of Arizona, Tucson, Ariz. '02

*Mann, William S., Met. and Cyanide Mgr., Montezuma Consolidated Gold Mining Co., Mirimar, Costa Rica, Central America (via New Orleans). '01

*Mannesmann, Robert......................................Remscheid, Germany. '90

*Mannheim, Ernest A., Min. Engr.............................Address wanted. '01

*Mannheim, P. A. L., Met., Perth Amboy Plant, American Smelting & Refining Co., Maurer, N. J. '89

*Mansfield, Nathan T.........................2124 Parker St., Berkeley, Cal. '96

*Marcy, Frank E., Chem. Engr., 307 Battery Park Bldg., 24 State St., New York, N. Y. '03

**Marengo, Paolo, Min. Engr......Boccheggiano, Minera, Grosseto, Italy. '04

*Markle, Alvan, Markle Banking and Trust Co.................Hazleton, Pa. '85

*Markle, John, Min. Engr., Managing Partner, G. B. Markle & Co., Jeddo, Pa. '79

*Marks, Mark M., Met., Care Tasmania Smelting Co...Zeehan, Tasmania. '05

*Marr, Robert A., Met. Engr...Union, Ore. '03

**Marriner, Jno. T., The Duff Development Co., Ltd., Care Paterson, Simons & Co., Singapore, Straits Settlements. '01

**Marriott, Hugh F., Cons. Min. Engr., Care Wernher, Beit & Co., 1 London Wall Bldgs., London, E. C., England. '05

*Marsh, Richard, Assayer....................107 S. Mill St., Spokane, Wash. '05

*Marshall, James J., Civ. and Min. Engr...Ansted, Lafayette Co., W. Va. '03

*Marshall, Winfred S., Mine Mgr....Lock Box 112, Ocean Springs, Miss. '03

*Martin, Dr. A. A., Min. Engr., Neustädtische Kirchstrasse 15, Berlin, N. W. 7, Germany. '00

**Martin, Edward P., Civ. Engr., Director of Guest Keen Co., Ltd., and Nettlefolds, Ltd., The Hill, Abergavenny, Monmouth, England. '81

*Martin, John Felix, Mgr., Dir., James Martin & Co., Ltd., Engineers & Founders, Gawler, South Australia. '93

*Martin, Nicholas J., Genl. Supt. of Companies Controlled by the North American Copper Co., Encampment, Wyo. '00

*Martin, Simon S., Supt., Steel Dept., Maryland Steel Co., 612 C St., Sparrows Point, Md. '99

*Martinez, Adolfo, Cia. Metallurgica Mexicana, San Luis Potosí, Mexico. '02

†Marvin, Charles D., Banker....................18 Wall St., New York, N. Y. '05

*Mason, James G., Care Robinson Deep Gold Mining Co., P. O. Box 1488, Johannesburg, Transvaal, South Africa. '05

*Mason, Russell T., Min. Engr.......228 South Pleasant St., Prescott, Ariz. '93

*Massenez, Joseph, Engr..........10 Humboldtstrasse, Wiesbaden, Germany. '91

*Masters, Harris K.....................................Instructed to hold all mail. '95

*Matcham, Charles A., Genl. Mgr., Lehigh Portland Cement Co., Allentown, Pa. '97

*Mather, Henry A., Chem....................52 Beaver St., New York, N. Y. '00

*Mather, Samuel, Merchant in Iron Ore, Pig Iron and Coal, Western Reserve Bldg., Cleveland, Ohio. '79

*Mather, William G., Prest., Cleveland Cliff Iron Co., Mercantile Bank Bldg., Cleveland, Ohio. '86

*Matheson, William G., Mgr., I. Matheson & Co., Ltd., New Glasgow, Nova Scotia. '85

*Mathews, Edward J.........71 Dexter Horton Bank Bldg., Seattle, Wash. '97

*Matthews, Frederick W., Min. Engr., P. O. Box 8, East Rand, Transvaal, So. Africa. '04

**Mathewson, E. P., Met., Mgr., Reduction Works, Anaconda Copper Mining Co., Anaconda, Mont. '89

*Mattern, Herman, Min. Mgr................................Lewistown, Mont. '02

*Mattes, Charles C., Civ. and Min. Engr., Genl. Mgr., Lackawanna Iron and Coal Co., 615 Lackawanna Ave., Scranton, Pa. '81

*Mattes, William F., Cons. Engr......615 Lackawanna Ave., Scranton, Pa. '81

*Matthiessen, F. W............Matthiessen & Hegeler Zinc Co., La Salle, Ill. '84

*Mauney, A. C., Cashier............Whitney Reduction Co., Gold Hill, N. C. '94

*Maurice Joseph, Min. Engr., Directeur de la Cie Miniére et Industrielle de Mansilla, Mansilla de la Sierra, Province de Logrono, Spain. '90

*Maurice, Juan, Min. Engr., Mgr., The Royal Silver Mines of Potosi, Bolivia, Ltd., Potosi, Bolivia, South America. '00

*Maxson, Chester W., Mine and Oil Investments, 1950 Park Grove Ave., Los Angeles, Cal. '02

*Maxwell, Frederick A. G., Met., Randfontein Estates Gold Mining Co., Randfontein, Transvaal, South Africa. '05

*Maxwell, Jno. W. C., Min. Engr....320 Sansome St., San Francisco, Cal. '02

*Maxwell, William, Mill Owner......Georgetown, Queensland, Australia. '04

**May, Albert Edward, Asst. Mgr., Eastern Oregon Mining Co., Bourne, Ore. '02

*May, De Courcy.........Prest., New York Shipbuilding Co., Camden, N. J. '79

**May, Jesse J., Mgr., Mine and Mill of Alma Gold Mining Co., Idaho Springs, Colo. '01

*May, Lawrence, Min. Engr., Care Mining Engr's Office,
Cananea Consolidated Copper Co., Cananea, Sonora, Mexico. '03

*Mayer, Lucius W., Min. Engr., Strattons Independence......Victor, Colo. '05

*Maynard, George W., Min. and Met. Engr., Prest., Monitor Copper Co.,
20 Nassau St., New York, N. Y. '71

*Maynard, Rea E., Min. Engr...............1310 Palm St., Los Angeles, Cal. '94

*Mayo, James H., Coal Operator, Mgr., Mindrineti Placer Mining Co.,
Paramaribo, Dutch Guiana, So. America. '82

*Meacham, Daniel B., Iron Mfr... ....Carew Bldg., Cincinnati, Ohio. '05

*Means, Ellison C., Prest. and Gen. Mgr., Low Moor Iron Co. of Va.,
Low Moor, Va. '88

*Means, John H., Min. Engr., Care Bewick, Moreing & Co.,
20 Copthall Ave., London, E. C, England. '97

*Meeker, David M., Foundryman, Vice-Prest. and Genl. Mgr.,
Meeker Foundry Co., Newark, N. J. '91

*Meeks, Reginald, Chem. and Met....17 West 84th St., New York, N. Y. '02

*Megraw, Herbert A., Met. and Engr., Director Cyanide Works,
The Iola Mining Co., Candon, N. C. '01

*Meier, Edward D., Prest. and Chief Engr., Heine Safety Boiler Co.,
11 Broadway, New York, N. Y. '86

*Meikleham, Thomas M. R., Mech. and Elec. Engr.,
44 Broad St., New York, N. Y. '04

*Mein, William W., Care Robinson Mine,
P. O. Box 1024, Johannesburg, Transvaal, So. Africa. '00

*Meissner, Carl A., Min. Engr., Care United States Steel Corporation,
71 Broadway, New York, N. Y. '00

*Meister, Herman C.............................2930 Geyer Ave., St. Louis, Mo. '77

*Melliss, D. Ernest, Cons. Min. and Civ. Engr., 208 California St.,
San Francisco, Cal. '00

*Melzer, Gustav E., Min. Engr. and Met., Mgr. and Treas. of the Eastern
Oregon Mining Co., Bourne, Baker Co., Ore. '00

*Menzies, Joseph F., Genl. Supt., Northwestern Improvement Co.,
Roslyn, Wash. '05

*Mercer, Harry T., Min. and Civ. Engr...................Trimountain, Mich. '05

*Mercer, John W., Genl. Mgr., South American Development Co.,
P. O. Box 336, Guayaquil, Ecuador, and 15 Broad St., New York, N. Y. '97

*Mercur, Robert S., Genl. Mgr., Kingston Coal Co............Kingston, Pa. '00

*Merricks, Frank, Min. Engr., 5 Great Winchester St.,
London, E. C., England. '92

*Merrill, Charles W., Met...........Homestake Mining Co., Lead, So. Dak. '92

*Merrill, Edward P., Genl. Supt., U. S. Coal & Oil Co.,
Holden, Logan Co., W. Va. '01

*Merrill, Frederick J. H., Geol., Room 1209, 60 Wall St., New York, N.Y. '85

*Merrill, George P., Head Curator Geol., U. S. National Museum,
Washington, D. C. '03

*Merriman, Mansfield, Prof. of Civil Engineering, Lehigh University,
South Bethlehem, Pa. '05

*Merry, Henry G., Genl. Mgr...Montana Coal & Coke Co., Electric, Mont. '89

†Merryweather, George, Genl. Western Agt., Coxe Bros. & Co., Inc.,
601 The Rookery, Chicago, Ill. '80

*Merton, Edward A., Min. Engr............Tepehuanes, Durango, Mexico. '03

†Merwin, Eugene W., Min. Engr.,
Care Promontorio Consolidated Mining Co., Nogales, Ariz. '03

*Messiter, Edwin H., Engr., Robins Conveying Belt Co.,
13 Park Row, New York, N. Y. '01
*Messler, Eugene L., Genl. Supt., Elize Furnaces, Coke Works,
Jones & McLaughlin Steel Co., Pittsburg, Pa. '97
*Mesta, George, Prest., Mesta Machine Co..708 Lewis Block, Pittsburg, Pa. '02
**Metcalf, Alfred T., Genl. Mgr., United Reefs (Sheba), Ltd.,
Eureka City, Transvaal, So. Africa. '91
*Metcalf, William..........1 Fulton St., Pittsburg, Pa. '94
*Metcalfe, G. W..........United States Smelting Co., West Jordon, Utah. '96
*Meyer, A. R..........318 Dwight Bldg., Kansas City, Mo. '86
*Meyer, Dr. Franz, Treas., Metallurgical Company of America,
52 Broadway, New York, N. Y. '03
*Mildron, Reginald B., Civ. and Min. Engr.,
816 Boston Bldg., Denver, Colo. '05
*Millard, Frank W., Min. Engr..........Ely, Nev. '03
*Millen, John D., Min. and Met. Engr., Mt. Bischoff Works,
Launceston, Tasmania. '05
*Miller, Alfred S., Prof. of Mining, Met. and Geology,
University of Idaho, Moscow, Idaho. '98
*Miller, Charles L., Genl. Supt., American Steel & Wire Co.,
Tradesmen Bldg., Pittsburg, Pa. '93
*Miller, Charles W., Min. Engr..........Barstow, Cal. '84
*Miller, D. Irving..........Sheffield, Ala. '02
*Miller, Edmund H., Prof. of Anal. Chem. and Assaying,
Columbia University, New York, N. Y. '95
*Miller, Emory T., Min. Engr..........Juragua Iron Co., Santiago, Cuba. '03
*Miller, George L., Min. Engr., Genl. Mgr.,
Kettle Creek Coal Mining Co., Bitumen, Pa. '05
*Miller, Harry E., Cons. Met. and Chem.,
331 Pine St., San Francisco, Cal. '01
*Miller, Harry H., Min. Engr., Met. and Chem., Genl. Mgr.,
Balsas Valley Co., Cons. Engr. to the Parral Corporation,
7 Nassau St., New York, N. Y. '95
*Miller, James, Bento Gold Estates, Ltd.,
Santa Barbara, Minas Garaes, Brazil, So. America. '95
*Miller, James W., Min. Engr., Balsas Valley Co.,
San Nicolos del Oro, Guerrero, Mexico. '05
*Miller, Joseph, Min. Engr., Knutsen & Miller, 53 Steamship Bldgs.,
Currie St., Adelaide, So. Australia. '99
*Miller, Leonard B., Lake Superior Iron Ore, Oglebay, Norton & Co.,
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*TARWATER, JAMES F., Contractor and Miner of Iron Ores..Rockwood, Tenn. '96
*TARWATER, POLK, Genl. Mgr., Ore Mines Brown Mining Co., Cardiff, Tenn. '00
*TATUM, LAWRENCE W., Min. Engr.......424 N. Y. Life Bldg., Chicago, Ill. '89
†TAYLOR, ADOLPHUS J., Solicitor, Citizens Chambers,
Moore St., Sydney, New South Wales, Australia. '05
**TAYLOR, ALBERT W., Care D. W. Deshler,
No. 7 Kaigan Dori, Kobe, Japan. '00
*TAYLOR, EDWARD J., Civ. and Min. Engr...229 N. Craig St., Pittsburg, Pa. '05
**TAYLOR, F. M., Prest., Taylor and Brunton Ore Sampling Cos.,
506 Boston Bldg., Denver, Colo. '01

*Taylor, Federico W., Min. Engr..Apartado 217, San Luis Potosi, Mexico. '81

**Taylor, James, Cons. Engr., Chem. and Met.,
Nyamagee, New South Wales, Australia. '98

*Taylor, Joseph J., Min. Engr.................................Chico, Butte Co., Cal. '90

*Taylor, Knox, Taylor Iron & Steel Co.......................High Bridge, N. J. '97

*Taylor, Lewis H., Jr., Mine Operator, 2030 Land Title Bldg.,
Philadelphia, Pa. '99

**Taylor, Percyvale, Min. Engr., 21 Victoria Road,
Kensington, London, W., England. '81

*Taylor, Roger, Met., Asst. Supt., Tacoma Smelting Co....Tacoma, Wash. '03

*Taylor, Samuel A., Cons. Civ. and Min. Engr.,
900 Lewis Block, Pittsburg, Pa. '05

*Taylor, William H., Mgr. and Prest., Anthracite Coal Companies,
131 Wyoming Ave., Scranton, Pa. '87

*Taylor, William W., Genl. Supt., Alleghany Ore & Iron Co.,
Clifton Forge, Va. '97

*Tays, Eugene A. H., Civ. and Min. Engr., San José de Gracia,
Sinaloa, Mexico. '98

**Teale, Joseph W., Min. Engr., Robinson Deep Gold Mining Co., Ltd.,
Box 1488, Johannesburg, Transvaal, So. Africa. '03

*Techow, Walter, Min. Engr., Mgr., Mountain View Mining Co.,
Bourne, Ore. '04

*Tefft, L. J., The Concord..Butte, Mont. '05

*Tellam, Alf., Chem.......................................Cananea, Sonora, Mexico. '05

*Temby, Edward T., Genl. Mgr., Tati Blue Jacket Syndicate, Ltd.,
Francistown, Matabeleland, South Africa. '05

*Temby, William T., Min. Engr., Langlaagte Est. Gold Mining Co.,
P. O. Box 98, Johannesburg, Transvaal, So. Africa. '03

*Tenny, Emil B., Supt., Blast Furnace, American Steel & Wire Co.,
Cleveland, Ohio. '92

*Terry, Laurence M., Princeton Club...72 East 34th St., New York, N. Y. '01

**Thacher, Arthur, Min. Engr., Prest., Central Lead Co., 420 Roe Bldg.,
St. Louis, Mo. '75

**Thacher, William A...Address wanted. '90

*Thackray, George E., Structural Engr., Cambria Steel Co..Johnstown, Pa. '80

*Thane, Bartlett L., Min. Engr., Supt., Eagle River Mining Co.,
Juneau, Alaska. '01

*Thayer, Benjamin B., Asst. to Prest., Amalgamated Copper Co.,
42 Broadway, New York, N. Y. '87

**Thies, Adolf.........................R. F. D., No. 1, Box 20, Charlotte, N. C. '78

**Thies, Ernst A., Mgr., Haile Gold Mining Co.....Haile Gold Mine, S. C. '00

*Thomae, W. F. A., Min. and Met. Engr.,
41 and 42 New Broad St., London, E. C., England. '93

*Thomas, Albert E., Min. Engr., P. O. Box 253,
Coolgardie, Western Australia. '97

*Thomas, Charles S., Min. Engr. and Met....P. O. Box 1117, Ouray, Colo. '04

*Thomas, Chester A., Min. Engr., Care F. H. Morrison,
1428 Bath St., Santa Barbara, Cal. '02

*Thomas, David R., Civil and Min. Engr., Care The Guanajuato Mining
& Milling Co., Apartado 33, Guanajuato, Mexico. '04

*Thomas, Edward G., Secy. and Treas., Independence Consolidated Gold
Mining Co., P. O. Box 94, Independence, Colo. '02

*Thomas, Edwin..Catasauqua, Pa. '79

*Thomas, Fred F., Prest. and Genl. Mgr., Gwinmine Dev. Co.,
Gwinmine, Calaveras Co., Cal. '84
*Thomas, George, 3d, E. B. Leaf & Co., Steel and Iron Brokerage,
1241 Real Estate Bldg., Philadelphia, Pa. '95
*Thomas, George W...Address wanted. '98
*Thomas, James A., Mech. Engr., Care Fulton Iron Works,
115 New Montgomery St., San Francisco, Cal. '05
*Thomas Kirby, Mining..........................317 Cooper Bldg., Denver Colo. '04
*Thomas, Marion L., Mine Supt..................Bonanza, Zacatecas, Mexico. '05
*Thomas, Richard A., Miner..........43 Exchange Place, New York, N. Y. '03
*Thomas, Samuel, Iron Trade..Catasauqua, Pa. '71
*Thomas, T. Lewis......................................38 Wall St., New York, N. Y. '99
*Thomas, William R., Care Bainbridge Seymour & Co.,
13 St. Helen's Place, London, E. C., England. '93
*Thomas, William S...Bevier, Mo. '96
*Thomlinson, William, Secy. and Genl. Mgr., Seaton Carew Iron Co.,
West Hartlepool, England. '81
*Thompson, Capt. Charles H...........1200 Brady Bldg., Los Angeles, Cal. '00
*Thompson, Heber S., Engr.........................Girard Estate, Pottsville, Pa. '76
†Thompson, Lavington G., M.D.........................Launceston, Tasmania. '03
*Thompson, Robert M., Chairman, Board of Directors,
International Nickel Co., 43 Exchange Place, New York, N. Y. '81
**Thompson, William, Cons. and Min. Engr.,
1 and 2 Great Winchester St., London, E. C., England. '99
*Thompson, William, Cons. Engr. and Genl. Mgr., Waterson Gold, Ltd.,
Ocampo, Chihuahua, Mexico. '00
*Thoms, Clifford C., Min Engr..Rialto, Cal. '03
*Thomson, E., Chem. and Engr.........................Pinos, Zacatecas, Mexico. '03
*Thomson, Ewen D. H., Mine Mgr., Gopeng Tin Mining Co.,
Gopeng, Perak, Federated Malay States. '05
*Thomson, Francis A., Met. Engr., Supt., New Western Reduction Co.,
P. O. Box 266, Goldfield, Nev. '02
*Thomson, John, Civ. Engr...................253 Broadway, New York, N. Y. '03
*Thomson, Samuel C., Cons. Engr., S. Neumann & Co., P. O. Box 485,
Johannesburg, Transvaal, So. Africa. '98
*Thorne, William E., Cons. Engr., Superintending Engr.,
Oro Grande Placer Mining Co., Dillion, Colo. '01
*Thornton, Edward T...............................Fox Chase, Philadelphia, Pa. '05
†Thornton, William D...Butte, Mont. '96
**Thow, Sydney, Civil Engr., Genl. Mgr., Hercules Gold & Silver
Mining Co., Mount Read, Tasmania. '02
*Throckmorton, Howard W., Min. Engr.......934 17th St., Denver, Colo. '03
*Thropp, Joseph E., Jr..Everett, Pa. '96
*Thurston, E. Coppee, Min. Engr., 804 Hayward Bldg., San Francisco, Cal. '96
*Thyng, William S., Min. Engr...411 Empire State Bldg., Spokane, Wash. '99
*Tiernan, Austin K., Min. Engr...............Box 441, Salt Lake City, Utah. '03
*Tierney, John J........................Prest., Pocahontas Co., Elkhorn, W. Va. '83
*Tierney, L. E., Genl. Mgr., Powhatan, Lynchburg, Elk Ridge &
Eureka Coal & Coke Co., Powhattan, McDowell Co., W. Va. '89
*Tillberg, Erik W., Min. Engr..............................Westervik, Sweden. '02
†Tillson, Benjamin F...........................132 Wall St., New Haven, Conn. '05
**Tilly, Alfred, Min. Engr., Supt., Frontino Bolivia Gold Mining
Co., Ltd., Puerto Berrio, Republic of Colombia, So. America. '99

**Timm, John M., Min. Engr., Mgr., Actiengesellschaft für Industrielle Sandverwertung, Basel, Switzerland. '96

*Tingle, Charles L., Mine Supt., Waldorf Mining & Milling Co., Georgetown, Colo. '03

*Tinstman, Benjamin E., Prest. and Genl. Mgr., Champlain Graphite Co., Whitehall, Washington County, N. Y. '03

*Tisdale, John N., Mining, Prest. and Genl. Mgr., Alaska-Snettisham Gold Mining Co., Snettisham, Alaska. '03

*Titcomb, Harold A., Min. Engr., Guggenheim Exploration Co., 53 Majestic Bldg., Denver, Colo. '99

*Titsworth, Frederick S., Civ. and Min. Engr., Care Wolcott, Vaile & Waterman, Equitable Bldg., Denver, Colo. '00

*Tobey, Horace P., Treas...........Tremont Nail Co., West Wareham, Mass. '89

*Tod, Herbert Noble, Min. Engr..........Box 453, Colorado Springs, Colo. '02

*Tod, Stuart, Min. Engr.........................Batopilas, Chihuahua, Mexico. '02

†Toedt, Emanuel B.........................Mgr., Fairbanks Co., Albany, N. Y. '92

*Toll, Abel H., Min. Supt......................Wallace Min. Co., Pitkin, Colo. '00

*Toll, Rensselaer H., Supt. Mancos Consolidated Gold Mining & Development Co., Mancos, Colo. '02

*Tom, Isidore............................30 Drayton Park, London, N. England. '04

*Tomlinson, Geo. H., Chem. Engr., Care Liquid Carbonic Co...Chicago, Ill. '02

*Tompkins, Charles H., Prest., American Diamond Rock Drill Co., 95 Liberty St., New York, N. Y. '99

*Tonkin, James J., Mgr., La Tortilla Lead Smelting Works, Calle Santa Engracia 2, Linares, Provincia de Jaen, Spain. '93

*Tonkin, John, Mine Supt.................2603 E. Broad St., Richmond, Va. '03

*Tonkin, Stanley J., Supt., Southwestern Development Co., Parsons, Kas. '03

*Tonking, James B.....Supt., New Jersey Zinc Co., Franklin Furnace, N. J. '90

*Tonking, William H., Supt. of Mines, Care B. Nicoll & Co., 59 Wall St., New York, N. Y. '96

*Tonnelé, Theodore, Metl. Engr., American Sheet Steel Co., McKeesport, Pa. '84

**Torrey, Herbert G., U. S. Assay Office, 30 Wall St., and Stirling Metal Co., 100 Broadway, New York, N. Y. '81

*Touceda, Enrique, Chem. and Met..............................Albany, N. Y. '89

*Toulmin, Priestley, Prest. and Genl. Mgr., Lehigh Coal Co., Lehigh, Ala. '88

*Touzeau, Edward M., Cons. Min. Engr., 30 and 31 St. Swithin's Lane, London, England. '91

*Tower, Charlemagne, Jr..............228 So. 7th Street, Philadelphia, Pa. '87

*Tower, George W., Jr., Geol. and Min. Supt., 321 North Excelsior Ave., Butte, Mont. '01

*Tower, Joseph T..............................542 Fifth Ave., New York, N. Y. '92

*Tower, Louis L., Min. Engr.......................................Northport, Wash. '03

*Towne, Robert S., Min. Engr., Prest., Compañia Metalurgica Mexicana, 82 Beaver St., New York, N. Y. '91

*Townsend, Arthur R., Met., Care Smuggler Union Mining Co., Telluride, Colo. '01

*Townsend, David, Cons. and Mech. Engr., etc., 624 Witherspoon Bldg., Philadelphia, Pa. '80

**Townsend, Harry P........Box 927, Johannesburg, Transvaal, So. Africa. '01

*Townsend, Henry T., Mech. Engr., Prest., Logan Iron & Steel Co., Bryn Mawr, Pa. '79

*Traphagen, Prof. Frank W., Prof. of Met. and Assaying, Colorado School of Mines, Golden, Colo. '99

*Tratman, E. E. Russell, Civ. Engr. and Editor, *Engineering News*, 1636 Monadnock Bldg., Chicago, Ill. '91

*Traylor, John A., Min. Engr., Western Mgr., Hodge Iron Co., 509 Equitable Bldg., Denver, Colo. '99

*Traylor, Samuel W., Mining Machinery, Engineering Bldg., 116 Liberty St., New York, N. Y. '03

**Treadwell, Erwin D., Mine Mgr., G. A. Treadwell Mining Co., Mayer, Ariz. '93

*Treat, F. H., Cons. Engr......................97 Heywood Ave., Orange, N. J. '86

*Tregloan, John R., Mine Supt., Mgr. and Owner.......Amador City, Cal. '00

*Trengove, Samuel R., Care Colonel Mining Co..........Crown King, Ariz. '00

*Treribe, Josiah H., Mine Supt., Montana Ore Purchasing Co., Butte, Mont. '03

*Treweeke, John, Mine Mgr. and Cons. Engr., 254 South 2d St., Salt Lake City, Utah. '02

*Trimble, A. J., Mine Operator......................................Sumpter, Ore. '87

*Trotz, J. O. Emanuel, Met.....U. S. Steel Corporation, New York, N. Y. '88

†Truax, Sewall, Institute Geologico de Mexico, 5A del Cipres, 2728, Mexico City, Mexico. '03

*Trumbull, Loyal W., Prof. of Min. and Geol., University of Wyoming, Laramie, Wyo. '04

*Trump, Edward N., Mech. and Chem. Engr., Chief Engr. and Genl. Mgr., Solvay Process Co., etc., Syracuse, N. Y. '96

Tschernoff, Prof. Dimitry C., Met., 25 Rue Pessotchnaya, St. Petersburg, Russia.

*Tsuno, T...Hagi, Yamaguchiken, Japan. '91

*Tucker, Albert W......Genl. Mgr., Seaboard Copper Co., Virgilina, Va. '00

**Tudor, William, Jr., Care H. D. Tudor, 82 Devonshire, St., Boston, Mass. '98

†Tulloch, Lindsay, U. S. Consul........................Launceston, Tasmania. '01

*Turner, George D. B., Civ. and Min. Engr., Vice-Prest. and Genl. Mgr., J. I. C. Mining & Milling Co., 259 Commercial Club Bldg., Salt Lake City, Utah. '99

**Turner, Henry W., Geol. and Min. Engr., Care Ladd Metals Co., Portland, Ore. '00

*Turner, John K., Min. Engr.........Care The Albany Hotel, Denver, Colo. '00

*Turner, R. Chester..............Room 36, 310 Pine St., San Francisco, Cal. '95

*Turner, William J., Perseverance Gold Mines, Ltd., Webster's Mine, Mt. Malcolm, Western Australia. '00

*Turney, Arthur R., Min. Engr., Woodford Lodge, Merton Park, Surrey, England. '03

*Tuschka, Otto, Assayer and Chem....Fundicion No. 2, Monterey, Mexico. '00

*Tuttle, Arthur L., Min. Engr., 434 King William St., San Antonio, Tex. '93

*Tyler, Nat., Jr., Topographer............136 Liberty St., New York, N. Y. '02

†Tyler, Victor M., Secy., Southern New England Telephone Co., New Haven, Conn. '05

*Tyrrell, Joseph B., Min. Engr.....................Dawson, Yukon Territory. '99

*Tyson, James W., Jr., Mine Mgr., Elizabeth Mining Co., South Strafford, Vt. '92

*Uehling, Edward A., Cons. Engr........135 Broadway, New York, N. Y. '86

*Underhill, James, Min. Engr., U. S. Mining Survey, Idaho Springs, Colo. '98

*Underwood, Arthur J., Min. Engr., 415 Lake View Ave., Jamestown, N. Y. '01

*Unger, J. S., Supt., Armor Plate Dept., Carnegie Steel Co.,
Munhall, Allegheny Co., Pa. '91
*Upham, W. E........ ....55 West 116th St., New York, N. Y. '01
*Utley, Howard H., Min. Engr., North Jellico Coal Co., Ltd.,
415 West Jefferson St., Louisville, Ky. '02

*Vail, Herbert E., Bellevue Proprietary, Ltd., Mt. Sir Samuel,
Western Australia. '05
*Vail, Richard H., Mining.....................413 S. Main St., Kewanee, Ill. '05
†Vaile, Joel F., Lawyer, Wolcott & Vaile, 420 Equitable Bldg., Denver, Colo. '95
*Valentine, Charles F., Cons. Min. Engr.,
Mt. Garnet, North Queensland, Australia. '02
*Valentine, Malvern R., Taylor & Brunton Sampling Co.,
Box 108, Victor, Colo. '03
*Valentine, M. D., Prest., M. D. Valentine & Bro. Co., Woodbridge, N. J. '76
*Vallat, Benjamin W., Min. Engr., Colorado Fuel & Iron Co.,
Sunrise, Wyo. '05
*Value, Beverly R., Engineer in Charge, Electrical Development Co.
of Ontario, Ltd., Niagara Falls, Ontario, Canada. '03
*Van Arsdale, Geo. D., Chem., Copper Queen Consolidated Mining Co.,
Room 68, 99 John St., New York, N. Y. '02
*Van Arsdale, W. H...Aurora, Ill. '72
*Van Barneveld, Charles E., Prof. of Min. Engineering,
University of Minnesota, Minneapolis, Minn. '01
*Van Brunt, Charles G., Chem....................Bridge St., Dedham, Mass. '98
*Van Cleve, Charles McK..............................Box 53, San Diego, Cal. '01
*Van Diest, Edmond C., Min. and Civ. Engr., P. O. Box 826,
Colorado Springs, Colo. '89
**Van Hise, Charles R....Prest., University of Wisconsin, Madison, Wis. '00
†Van Ingen, Dudley A., Chem............................ ....Palmerton, Pa. '95
*Van Isschot, Pierre E. C...Casilla 240, Guayaquil, Ecuador, So. America. '96
*Van Law, Carlos W., Mech. Engr., Genl. Mgr., Guanajuato Reduction
& Mines Co., Guanajuato, Mexico. '04
*Van Liew, Willard R., Smelter Supt., Care F. A. Mattevich & Co.,
Batoum, So. Russia. '03
*Van Mater, Joseph A., Cons. Engr., Genl. Mgr., The Bertha
Mineral Co., Pulaski, Va. '93
*Van Ness, William W., Min. Engr.,
622 Salisbury House, London Wall, London, E. C., Eng. '97
†Van Nostrand, Charles B., Treas., United Mining Co. and
White Knob Copper Co., 36 Wall St., New York, N. Y. '02
*Van Orden, Frank L., Min. Supt., Wyandot Copper Co., Houghton, Mich. '01
*Van Slyke, Frederick E., Elec. and Min. Engr., Jeffrey Mfg. Co.,
Columbus, Ohio. '01
*Van Zwaluwenburg, A., Eastern Editor *The Iron Trade Review*,
150 Nassau St., New York, N. Y. '00
**Varden, Richard A., Cons. Min. Engr.,
1 St. Helen's Place, London, E. C., England. '87
††Varicle, Dr. Jean A.................................Dawson, Yukon Territory. '05
*Vauclain, Samuel M., Supt., Baldwin Locomotive Works,
500 N. Broad St., Philadelphia, Pa. '96
*Vaughen, Samuel W., Supt. of Furnaces, National Tube Co.,
682 14th Ave., Lorain, Ohio. '04

*Vaux, Charles A., Min. Engr., P. O. Box 80, East Rand, Transvaal, South Africa. '04
**Veatch, John A., Min. and Hydraulic Engr., Darien Gold Mining Co., Ltd., Cana, Rep. of Colombia, So. America, Letters to 615 Pearl St., Napa City, Cal. '01
*Veitch, Alexander, Asst. Mgr., Arizona Copper Co., Ltd., Clifton, Arizona. '03
*Vidler, Louis W., Mine Engr., Supt., Trans-Continental Transportation & Mining Co., etc. Georgetown, Colo. '04
*Vidler, Rees C., Min. Engr., Genl. Mgr., Transcontinental Transportation & Mining Co., Georgetown, Colo. '05
*Viele, Maurice A., Civ. and Hydraulic Engr., 44 Broad St., New York, N. Y. '02
*Vigeon, Edward C., Met., Asst. Genl. Mgr., Societé des mines de Cuivre de Catémou, Casilla 1000, Valpariso, Chili, South America. '03
*Viggers, William, Mech. Engr..............Apartado 90, Durango, Mexico. '89
*Vincent, Hobart S., Mine Supt.....................Deadwood, South Dakota. '05
*Vivian, George G., Min. and Met. Engr., Vice-Prest. and Genl. Mgr., Hidalgo Mining & Milling Co., Sultepec, Mexico, Mexico. '82
*Vivian, Godfrey T., Min. Engr., Pengegon House, Camborne, Cornwall, England. '97
*Vogelsang, Dr. Karl, Min. Engr., Direktor, Koenigl. Berginspektion, Bleicherode a Harz, Germany. '01
*Voorheis, Edward C., Mine Mgr...162 Crocker Bldg., San Francisco, Cal. '99
*Voskule, Gedeon A., Min. Engr., Transvaal Goldfields, Ltd., P. O. Box 550, Johannesburg, Transvaal, South Africa. '05

†Wackenhut, George J., Mining, 531 E. Pike's Peak Ave., Colorado Springs, Colo. '04
*Wadsworth, M. E., Prof. of Min. and Geol., Pennsylvania State College, etc., State College, Pa. '89
*Wagner, Henry R., Agt., American Smelting & Refining Co., 120 Bishopsgate St. Within, London, E. C., England. '02
*Wagner, John L...Prest., Wagner Palenros Mnfg. Co., Fairmont, W. Va. '00
*Wagoner, Luther, Civ. and Min. Engr., 849 Chestnut St., San Francisco, Cal. '97
*Wainwright, J. Howard, Chem..........159 Front St., New York, N. Y. '04
*Wainwright, William E., Genl. Mgr., Broken Hill South Silver Mining Co., Broken Hill, South Blocks, New South Wales, Australia. '03
*Wait, Charles E., Prof. of Chem., University of Tennessee, Knoxville, Tenn. '79
*Walcott, Charles D., Director, U. S. Geological Survey, 1330 "F" St., Washington, D. C. '92
*Waldo, Dr. Leonard, Cons. Engr., Room 408, 49 Wall St., New York, N. Y. '88
*Walker, Arthur L., Mgr., Perth Amboy Plant, American Smelting & Refining Co., Perth Amboy, N. J. '85
*Walker, Etheridge, Assayer..Gazelle, Cal. '02
*Walker, Elton W., Supt., Tombstone Consolidated Mines, Ltd., Tombstone, Ariz. '01
*Walker, J. C............................552 North Broadway, Yonkers, N. Y. '83
†Walker, John A., Vice-Prest., Joseph Dixon Crucible Co., Jersey City, N. J. '78

†WALKER, W. IRVING, Road Builder, R. F. D. No. 1.......Millington, Md. '04
*WALKER, W. R., Chem. U. S. Steel Corp., Empire Bldg., New York, N. Y. '81
*WALL, ENOS A., Min. and Met., Vice-Prest., Utah Copper Co.,
320 D. F. Walker Bldg., Salt Lake City, Utah. '87
*WALLACE, H. VINCENT, Min. Engr., Mgr., Sombrerevillo Mining Co.,
Saric, Sonora, Mexico. '03
*WALLACE, JAMES P., Genl. Mgr., Monmouth Mining & Development Co.,
Kingman, Ariz. '97
*WALLACE, LOUIS R., Met.........Detroit Copper Mining Co., Morenci, Ariz. '99
**WALLER, DR. ELWYN, Anal. and Cons. Chem.,
159 Front St., New York, N. Y. '83
*WALLER, GEORGE A., Geol. Surveyor..................Queenstown, Tasmania. '94
*WALLER, RICHARD F., Min. Engr............................Zeehan, Tasmania. '03
*WALLIN, GUSTAF, Min. Engr...Falun, Sweden. '02
*WALLIS, H. BOYD, Min. Engr. and Met.,
Goldbergwerk, Ronday, Post Zwestow, b. Wottitz, Bohemia. '04
*WALLIS, PHILIP, Supt. Motive Power, Long Island R.R.,
Richmond Hill, N. Y. '84
**WALSH, THOMAS F., Mine Operator,
1420 New York Ave., Washington, D. C. '00
*WALTER, BRUCE.....................................323 Evaline St., Pittsburg, Pa. '05
*WALTER, E. W., Met...Supt., Kendrick & Gelder Sm. Co., Silverton, Colo. '93
*WANG, CHUNG YU, Geol. and Mining Engr., Care Lin Fong & Co.,
29–31 West Houston St., New York, N. Y. '05
*WANLESS, GEO. JAS., Assayer and Chem., Ore Purchasing Agt.,
American Smelting & Refining Co., El Paso, Texas. '02
**WARD, OSMER B., Met., Hannan's Star Gold Mines,
P. O. Box 158, Kalgoorlie, Western Australia. '98
*WARD, WILLARD P., Min. Engr..Mills Bldg., 15 Broad St., New York, N.Y. '71
†WARD, WILLIAM F., Asst. Engr...Conrey Placer Mining Co., Ruby, Mont. '03
*WARDEN, BRUCE R., Min. Engr., Mining Dept.,
Canadian Pacific Ry. Co., Banff, Alberta, N. W. T., Canada. '02
*WARDMAN, GEORGE B., Assayer and Chem., Apartado 24,
Aguascalientes, Mexico. '95
*WARN, JOHN E., Min. Mgr....Neroigunoah, New South Wales, Australia. '05
*WARNE, HENRY H., Mining.........................Instructed to hold all mail. '89
*WARNER, WILLARD, JR., Supt. Blast Furnace, Roane Iron Co.,
Rockwood, Tenn. '92
*WARREN, HENRY B., Min. Engr. and Surveyor,
1043 Burrard St., Vancouver, B. C., Canada. '99
*WARRINER, RUEL C., Min. Engr., Acting Genl. Mgr., Bonanza, Ltd.,
Box 149, Johannesburg, Transvaal, So. Africa. '03
*WARRINER, SAMUEL D., Genl. Mgr., Lehigh Valley Coal Co.,
Wilkes-Barre, Pa. '91
**WARTENWEILER, ALFRED.................Crocker Bldg., San Francisco, Cal. '75
*WARTENWEILER, FRED., Met........................ ...P. O. Box 16, Napa, Cal. '03
*WASTE, HARRY L., Asst. Mine Mgr., Mariposa Commercial Mining Co.,
Mt. Bullion, Cal. '05
**WATERS, ALBERT L., Mine Engr.....Matehuala, San Luis Potosi, Mexico. '93
*WATERS, STEPHEN, Mech. and Elect. Engr., Supt., Grinding and
Concentrating Depts., Cia. Real del Monte y Pachuca, Hacienda de Loreto,
Pachuca, Mexico. '02

*WATKINS, A. OCTAVIUS, Senior Asst. Assayer, Royal Mint,
Perth, Western Australia. '98
*WATKINS, THOMAS H., Room 410, Whitehall Bldg., 17 Battery Place,
New York, N. Y. '04
*WATSON, CHARLES E., Mine Supt.................Beatty (via Goldfield), Nev. '02
*WATSON, CHARLES S., Anal. Chem. and Met.,
Greenmount Gold Mines, Ltd., Southern Cross, Western Australia. '00
†WATSON, FRANK W..........................112 Sherlock Bldg., Portland, Ore. '03
*WATSON, RALPH W......122 East South Temple St., Salt Lake City, Utah. '90
*WATSON, ROBERT W., Mining.................P. O. Box 473, Harrisburg, Pa. '00
*WATSON, ROLLA B., Cons. Min. Engr., Care Shannon Copper Co.,
Clifton, Ariz. '95
*WATSON, PROF. THOS. L., Prof. of Geol.,
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*WATSON, WINFIELD S...Address wanted. '01
*WATT, J. HENRY..........................425 Whitney Ave., Wilkinsburg, Pa. '97
*WATTERS, DANIEL M., Cons. Engr.,
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*Williams, Lewis, Mine Owner and Met.......Napoleon Mine, Milton, Cal. '83
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**YOUNG, GEORGE J., Prof. of Min. & Met., University of Nevada, Reno, Nevada. '00
*YOUNG, HENRY S., Min. Engr., Mgr., Bau Mines of Borneo Co., Ltd., Bau Kuching, Sarawak, Borneo, Dutch East Indies. '03

*YOUNG, JAMES S., Met., Ashanti Goldfields Corporation, Ltd.,
Ayeinm, Gold Coast Colony, West Africa. '95
*YOUNG, JOHN W., Genl. European Mgr., Allis-Chalmers Co.,
533 Salisbury House, Finsbury Circus, London, E. C., England. '94
*YOUNG, J. W. R., Strathmore, Eastern Road, East Finchley, N.,
London, England. '91
*YOUNG, LEWIS E., Prof. of Min. Engineering,
Colorado School of Mines, Golden, Colo. '01
*YOUNG, WAYLAND H., Min. Engr.........306 Pine St., San Francisco, Cal. '04
*YOUNG, WILLIAM, Magistrate, P. O. Box 57, Rat Portage, Ontario, Canada. '04
*YUNG, MORRISON B., Mine Supt., El Cobre Mines, Santiago de Cuba, Cuba. '02

*ZAMBRANO, ADOLPHO, Miner, Secy., Monterey Steel Works,
Monterey, Mexico. '02
*ZEHNDER, C. H., Pig Iron Manfr.,
1218 Pennsylvania Bldg., Philadelphia, Pa. '87
*ZELLER, FRANK M., Vice-Prest. and Secy., Continental Mnfg. Co., etc.,
Old Stock Exchange, Philadelphia, Pa. '00
*ZERBEY, FREDERICK E., Min. Engr., 93 West Union St., Wilkes-Barre, Pa. '92
*ZERN, E. N..Sturgis, Ky. '04
*ZIMMERMAN, ADOLPH A., Chemist and Assayer..................Helena, Mont. '96
†ZINTGRAFF, E..........................Hoboken-les-Anvers, Antwerp, Belgium. '98
*ZWICKY, WILLIAM E., Mine Mgr., Rambler-Cariboo Mine, Ltd.,
Kaslo, B. C., Canada. '05

Honorary Members	8
Members	3,685
Associates	193
Total	3,886

Deceased.

Elected.		Died.
1903	*Adams, Charles C.	1905
1884	*Addy, Matthew	1896
1894	*Allen, R. B.	1896
1874	*Amiot, H.	1892
1886	*Amsler, Carl	1894
1898	**Anderson, John W.	1905
1895	*Ångström, Carl	1901
1890	*Armstrong, John F.	1898
1882	*Arnolds, Hugo	1886
1875	*Ashburner, Charles A.	1889
1872	*Ashburner, William	1887
1883	*Atkins, C. M., Jr.	1885
1897	*Ayers, William	1898
1885	*Babcock, Geo. H.	1893
1884	*Bailey, Edward	1889
1880	*Bailey, Jackson	1887
1900	*Ballou, Franklin	1903
1886	*Barnes, F. W.	1892
1884	†Barns, George T.	1900
1884	*Barr, J. N.	1904
1888	*Barrett, D. H.	1888
1877	*Bartlett, J. C.	1903
1901	*Batterman, C. S.	1901
1891	*Becher, H. M.	1893
1882	*Beeger, H.	1892
1888	*Bell, George A.	1902
1892	*Bell, G. B.	1893
1874	**Bell, Sir Lowthian**	1904
1889	*Bennett, David A.	1897
1899	*Best, John W.	1904
1875	*Bierwith, L. C.	1902
1882	*Billing, G.	1890
1875	*Blackwell, Edward	1880
1877	*Blake, F. C.	1891
1903	*Blandy, A. Poyntz	1903
1871	*Blandy, John F.	1903
1871	*Blossom, T. M.	1876
1893	**Boericke, Rudolph	1897
1887	*Boies, Henry M.	1903
1892	*Booth, Edgar H.	1898
1875	*Borda, E.	1897
1891	*Bosher, C. H.	1894
1871	*Bowden, James H.	1900
1886	*Bowman, Amos	1894
1886	*Boyle, Thomas G.	1890
1887	*Braden, S.	1894
1879	*Brainerd, A. F.	1893
1871	*Bramwell, J. H.	1894
1879	*Bridgman, H. L.	1900
1881	*Briggs, Robert	1882
1880	*Brinsmade, J. B.	1884
1880	*Brown, A. C.	1890
1872	*Brown, A. J.	1875
1890	**Browne, Arthur R.	1900
1882	*Browning, F. D.	1885
1885	*Brückner, Wm.	1887
1890	†Brunings, J. H.	1893
1901	*Bryan, Luke W.	1905
1896	*Bucke, M. A.	1899
1900	†Buell, P. A.	1900
1874	*Bullock, M. C.	1899
1876	*Bunsen, Robert	1887
1872	†Butler, Cyrus	1890
1900	*Butler, W. P.	1903
1893	*Button, Edward	1900
1886	*Byers, Alexander M.	1900
1903	*Cade, Edwin Arthur	1903
1876	*Caldwell, W. B., Jr.	1880
1878	*Cameron, James R.	1881
1897	**Campbell, William Y.	1899
1876	†Canfield, A. Cass	1904
1893	*Carkeek, John	1900
1878	*Carnegie, Thomas M.	1886
1891	*Carpenter, J. H.	1898
1897	†Carrel, F. J.	1894
1887	*Carroll, Michael	1891
1901	*Carroll, William E.	1904
1893	*Cary, John S.	1899
1878	*Case, W. H.	1898
1892	***Castillo, A. del**	1895
1873	*Chalfant, John W.	1898
1886	*Chambers, R. C.	1901
1882	*Chanute, Arthur	1895
1879	*Chaper, Maurice	1896
1882	*Cheever, B. W.	1888
1871	*Chester, A. H.	1903
1875	*Chisholm, Henry	1881
1897	†Chisholm, S. S.	1901
1890	*Clark, C. J.	1896
1874	*Clark, Ellis	1895
1877	*Clark, Henry G.	1881
1887	*Clark, Joseph K.	1903
1872	*Clark, R. Neilson	1894
1881	*Clark, William	1884
1874	*Clayton, Joshua	1889
1883	*Clayton, W. S.	1886
1887	**Clement, Victor M.	1903
1876	*Clemes, J. P.	1876
1891	*Coghlan, F. M.	1903
1896	*Cole, Harold M.	1902
1895	*Collins, Arthur L.	1902
1876	†Collins, H. E.	1896
1881	*Conant, T. P.	1891
1888	*Conro, Albert	1901
1902	**Contreras, Manuel M.**	1902
1882	*Converse, James B.	1883
1891	*Conyngham, C. M.	1894
1874	*Cook, George H.	1886
1902	*Coom, Henry	1903
1874	*Cooper, Edward	1905
1899	†Corbett, Francis E.	1901
1871	*Coryell, Martin	1892
1891	*Cowland, C. D.	1894
1886	*Cowles, E. H.	1892
1871	*Coxe, Eckley B.	1895
1874	*Coxe, W. E. C.	1904

Elected.		Died.
1871	*Crafts, Walter	1896
1887	*Craven, Frank S.	1889
1887	*Craven, Henry S.	1889
1879	*Crocker, William B.	1885
1879	*Curry, Henry M.	1900
1871	*Daddow, S. H.	1875
1884	*Dagron, J. G.	1895
1872	**D'Aligny, H. F. Q.	1875
1883	*Darley, E. C.	1901
1891	†Darling, J. V.	1892
1891	*Darling, W. P.	1896
1887	***Daubrée,A**	1896
1877	*Davenport, Russell W.	1904
1900	*Davidow, Isidor	1904
1882	*Davidson, D. R.	1884
1899	†Davidson, Louis	1903
1881	*Davies, Edw. S.	1885
1887	*Davies, W. B.	1891
1886	†Davis, M. C.	1886
1884	†Dayton, L. M.	1892
1883	*De Camp, A. H.	1895
1885	*De Camp, Edw. F.	1895
1875	*De Camp, William S.	1905
1872	**De Crano, E. G.	1893
1880	*De Peiger, R. F. J.	1883
1881	*Desloge, John M.	1900
1902	*Dickerson, Clarence M.	1903
1883	*Dickson, Thomas	1884
1902	*Dillon, Ralph	1902
1884	*Disston, Horace C.	1902
1886	*Disston, Thomas S.	1895
1902	*Dobler, F. C.	1903
1884	*Dodge, Wallace H.	1895
1900	**Dodge, William E.	1903
1892	*Dodson, R. T.	1896
1897	*Doerr, Edward	1904
1882	*Dominick, F. J.	1895
1879	*Dorsey, E. B.	1900
1875	†Dresser, Charles A.	1873
1871	**Drown, Thomas M.**	1904
1900	*Du Bois, Louis C.	1903
1889	*Duffield, P. W.	1897
1876	*Durfee, W. F.	1899
1881	*Dwight, W. S.	1884
1871	*Egleston, Thomas	1900
1889	*Eldridge, George H.	1905
1879	†Ely, E. B.	1884
1891	*Ely, George H.	1894
1881	*Emanuel, W. H.	1901
1876	*Emerson, B. F.	1884
1880	*Emery, Charles E.	1898
1872	*Engelmann, Henry	1899
1893	†Escobar, Mario	1901
1880	*Evans, John D.	1891
1883	*Fegely, Isaac	1891
1881	*Felton, S. M.	1884
1878	*Ferguson, E. M.	1904
1876	*Fernekes, Anton	1887
1886	*Ferris, G. W. G., Jr.	1896
1872	*Firmstone, William	1875
1876	*Fisher, Harvey	1889
1880	*Fisher, H. H.	1888
1875	*Foote, Herbert C.	1880
1882	*Ford, Robert G.	1891
1903	*Foster, Clement Le Neve	1904
1888	*Francis, A. G.	1890
1871	*Frazier, B. W.	1905
1878	*Freeman, H. C.	1900
1877	†Freeman, William C.	1903
1894	*French, Aaron	1902
1877	†Fuller, John T.	1885
1898	*Fuller, T. E.	1898
1891	*Fulton, G. E.	1895
1888	*Furlonge, W. H.	1896
1880	*Furman, H. Van F.	1902
1890	***Gaetzschmann, Moritz**	1895
1878	*Gardner, G. Clinton	1904
1881	*Garrett, William	1903
1884	†Gatewood, R.	1890
1894	*Gibson, W. K.	1898
1883	*Gilbert, Edward G.	1893
1882	*Goetz, G. W.	1897
1897	*Goodwillie, J. B.	1898
1871	†Goodwin, H. S.	1892
1876	*Gould, Robert A.	1878
1872	†Gowen, Franklin B.	1889
1890	*Gracey, F. P.	1895
1875	†Graham, Thomas	1892
1896	*Grant, John A.	1897
1877	*Gridley, Edward	1887
1874	*Griffen, John	1884
1894	*Grubb, E. B.	1899
1871	***Gruner, L.**	1883
1898	*Guenther, Albert	1899
1883	*Gurley, William	1887
1883	*Hadley, W. C.	1896
1879	*Hahn, Ignatius	1888
1888	*Hainsworth, William	1896
1891	*Halder, Albert H.	1901
1881	*Hall, James F.	1884
1888	*Hall, Jesse	1902
1894	*Hamilton, Walker	1895
1889	*Hammer, Hakon	1896
1895	*Harlow, Mellen S.	1901
1900	*Harmon, Dana	1903
1874	*Harnickell, A.	1887
1872	*Harris, Stephen	1874
1871	*Harris, Wm. J.	1904
1877	†Hart, W. R.	1892
1890	*Hartung, Max J.	1894
1880	†Harvey, William H.	1888
1894	*Hayden, Edward S.	1899
1887	†Hazard, Rowland	1898
1881	*Healy, Maurice	1881
1883	*Heard, John, Jr.	1895
1902	*Heckelmann, Otto	1902
1893	*Heckscher, Richard P.	1903
1873	*Heinrich, Oswald J.	1886
1875	*Hemphill, James	1900
1892	*Henry, Adolph	1892
1871	*Hewitt, Abram S.	1903
1890	*Hicks, Geo. J.	1891
1894	*Hildreth, R. W.	1895
1889	*Hillman, Daniel	1890
1891	*Hinton, F.	1895
1880	*Hoatson, Thomas	1897
1885	*Hodgson, Thomas	1896

Elected.		Died.
1888	**Hoefer, Eugene	1899
1875	*Holbrook, F. N.	1902
1887	†Holden, E. F.	1899
1899	*Holdsworth, Frank A.	1902
1871	*Holley, A. L.	1882
1887	*Hollister, O. J.	1892
1875	*Holloway, J. F.	1896
1878	*Hooper, William	1902
1890	*Hopke, Frank E.	1890
1877	*Horton, N. W.	1886
1899	*Hosie, James P.	1898
1891	*Hosking, George F.	1895
1894	*Hoskold, H. D.	1904
1886	*Howard, T.	1896
1886	*Huhn, E. C. O.	1894
1881	*Hulbert, Thomas H.	1889
1872	*Humphreys, A. W.	1894
1882	*Hungerford, Wm. S.	1904
1879	*Hunt, Alfred E.	1899
1871	*Hunt, Joseph	1897
1878	*Hunt, Joshua	1886
1871	*Hunt, Thomas	1872
1871	*Hunt, T. Sterry	1892
1879	*Hussey, C. C.	1884
1880	*Hyndman, E. K.	1884
1879	*Ingersoll, S. Warren	1884
1876	*Inman, A. L.	1894
1890	*Ireland, Thomas A.	1902
1900	*Irish, Dana C.	1905
1872	*Irving, R. D.	1888
1881	†Irwin, John H.	1890
1882	*James, Isaac E.	1887
1879	*James, Reese	1899
1895	*Jamieson, M. B.	1895
1885	*Janin, Alexis	1897
1874	*Janney, Morris P.	1898
1901	*Jenkins, Thomas	1902
1874	*Jenney, F. B.	1876
1873	*Jernegan, J. L.	1881
1892	*Jessop, William H.	1900
1879	*Johnson, Isaac G.	1902
1898	†Johnson, William E.	1901
1881	*Johnston, W. N.	1886
1878	*Jones, B. F.	1903
1875	*Jones, D. N.	1889
1887	*Jones, Edward	1892
1881	*Jones, Griffith	1888
1875	*Jones, W. R.	1889
1888	*Jousselin, A. L.	1897
1888	*Kelly, G. D.	1892
1890	**Kerl, Bruno**	1905
1876	*Kerr, Prof. W. C.	1885
1882	*Kimball, Hiram	1899
1899	**King, Clarence	1901
1897	†King, Porter	1901
1882	*Kingsley, J. Cook	1899
1890	*Knight, Fletcher H.	1903
1900	*Knight, Wilbur C.	1903
1897	*Koch, E. C.	1898
1891	*Koehler, Walter J.	1901
1895	*Kornberg, G. A.	1901
1891	*Kreischer, C. G.	1891
1884	*Kriete, Henry C.	1890
1890	*Kurimoto, Ren	1892

Elected.		Died.
1896	*Labram, George	1900
1876	*Lamborn, R. H.	1894
1882	**Landis, Edward K.	1904
1883	*Landsburg, E.	1888
1887	**Larnach, W. J. M.	1898
1892	*Lavaleye, E. de	1892
1895	***Le Conte, Joseph**	1901
1899	†Lee, Harry H.	1905
1876	*Lee, R. H.	1895
1876	*Lee, R. H.	1892
1871	†Lee, Washington	1872
1882	*Leisenring, E. B.	1894
1875	*Leisenring, John	1874
1902	*Lengemann, Aug	1904
1896	**Lesley, J. P.**	1903
1881	*Lewis, David B.	1887
1875	*Lewis, James F.	1901
1871	*Liebenau, Charles von	1875
1887	*Lienau, D. B.	1890
1896	*Linderman, Robert P.	1902
1900	*Lindsay, Edward N.	1900
1902	*Lindsay, William A.	1905
1889	*Lindsay, William W.	1902
1891	*Loane, W. E.	1896
1891	*Lobdell, Geo. G.	1894
1873	*Loiseau, E. F.	1886
1871	†Lord, John C.	1872
1882	*Lord, R. F.	1899
1874	*Lorenz, W.	1884
1881	*Lorenz, W., Jr.	1881
1879	*Lowe, Francis A.	1883
1894	*Luckraft, J. S.	1903
1884	*Luther, R. C.	1905
1888	*McCalley, Henry	1904
1879	*McCandless, E. V.	1903
1897	*McCartney, Robert J.	1904
1871	*McClellan, Arthur	1904
1874	*McCormack, Henry	1900
1885	*McGinnis, J. W.	1891
1877	*McIntire, Henry M.	1880
1880	†McKee, David	1884
1883	*McKeown, S. W.	1898
1899	*McLean, Gordon	1905
1871	*McNair, Thos. S.	1902
1902	*McNamara, Herbert H	1905
1876	*Mackintosh, J. B.	1891
1881	†Mackintosh, W. S.	1884
1898	†MacLaren, Duncan	1901
1886	*MacLean, F. P.	1891
1874	*MacMartin, Archibald	1881
1876	*Macy, Arthur	1891
1894	†Macy, Charles A., 2d	1901
1874	*Maffet, W. R.	1891
1888	*Mahony, Arthur S. J.	1904
1887	*Manness, Charles F.	1887
1878	*Manthey, William	1883
1890	**Manzavino, N.	1899
1880	*March, W. J.	1891
1887	*Marsh, Charles W.	1896
1888	*Marsh, Walter	1897
1879	*Martine, Charles A.	1900
1878	*Marvin, Selden E.	1899
1887	*Matthews, C. W.	1891
1874	*Maury, M. F.	1886

Elected.		Died.
1882	†Means, Archibald	1898
1899	*Mellors, Paul	1902
1871	*Mercur, Frederick	1888
1900	*Messer, Edgar H.	1902
1882	*Michaelis, O. E.	1890
1875	*Mickley, J. W.	1880
1898	*Middleton, W. B.	1899
1877	*Miles, Fred P.	1897
1893	*Miller, C. H.	1896
1875	*Miller, Reuben	1890
1877	*Mills, James E.	1901
1882	*Moen, Philip W	1904
1871	*Moffat, E. S.	1893
1891	*Moister, I. R.	1896
1889	*Molson, J. H. R.	1897
1877	*Moore, Charles W.	1877
1895	*Moore, E. W. S.	1895
1875	*Moore, James	1901
1879	*Morgan, J.	1892
1878	*Morgan, Thomas R.	1897
1879	*Morison, George S.	1903
1895	*Morley, B. F.	1903
1874	*Morris, S. Fisher	1901
1881	*Morse, H. G.	1903
1899	*Moulder, H. L.	1903
1883	*Nason, Henry B.	1894
1879	*Neilson, James	1893
1895	*Nelson, W. S.	1897
1885	*Newberry, W. E.	1899
1871	*Newton, Henry	1877
1874	*Newton, Isaac	1884
1873	*Nichols, Edw.	1892
1893	*Nichols, N. J.	1896
1882	*Nicholson, A. H.	1887
1888	**Nitze, H. B. C.	1900
1881	*Noble, Samuel	1888
1882	*Norton, F. O.	1893
1887	*O'Farrell, John J	1888
1888	*Oliver, William	1890
1881	†Oothout, E. A.	1894
1887	*Osgood, F. C.	1903
1894	*Owen, Frank	1901
1886	†Owen, J. R. D.	1887
1882	*Paddock, John H.	1903
1900	*Page, Clarence V.	1903
1873	†Painter, A. E. W.	1903
1874	*Painter, Howard	1876
1872	*Park, James, Jr.	1883
1887	†Parker, O. B.	1891
1898	*Parker, William J., Jr	1905
1875	*Parkin, Charles	1904
1900	*Parks, James F.	1903
1875	*Parks, John C.	1902
1874	*Parsons, Charles O.	1894
1890	***Patera, Adolph**	1890
1886	*Patterson, R. P.	1904
1888	*Patterson, W. E.	1896
1889	*Paul, Henry	1904
1885	***Percy, John**	1889
1882	**Peters, J. C.	1899
1883	*Peters, Samuel	1899
1902	*Petersdorff, C. F. von.	1903
1871	**Petter, William H.	1904
1888	*Pettibone, Augustus	1890

Elected.		Died.
1877	*Phelps, Walter	1878
1895	*Philips, Joseph, Jr.	1905
1891	*Phillips, A. G.	1903
1882	†Phillips, P. E.	1884
1882	†Pierson, O. H	1882
1872	*Platt, Franklin	1900
1873	**Platt, J. C.	1898
1875	*Platt, W. G.	1885
1872	*Pleasants, Henry	1880
1880	*Plummer, J. W.	1896
1889	**Pomeroy, James H.	1903
1884	*Porter, Geo. A.	1892
1887	***Pošepný, Franz**	1895
1886	*Potts, J. D.	1893
1900	*Powell, John Henry	1903
1899	*Powell, John R.	1902
1886	*Pratt, N. W.	1896
1885	*Price, E. A.	1898
1887	*Price, J. A.	1892
1875	†Priest, J. R.	1880
1881	*Prince, F.	1892
1889	*Quintard, E. A.	1903
1889	*Ramsay, M.	1892
1876	*Rand, Addison C.	1900
1882	*Rand, Jasper R.	1900
1873	**Rand, Theodore D.	1903
1879	*Randol, James B.	1903
1891	*Rawling, Charles Q.	1902
1892	†Reddy, P.	1900
1892	*Reed, H. L.	1893
1889	*Reid, J. M.	1895
1883	*Reinhardt, H. O.	1894
1896	†Rich, Jacob M.	1903
1875	*Richards, George	1900
1884	**Richards, John T.	1896
1871	*Richter, C. E	1877
1883	***Richter, Theodor**	1898
1884	*Rickard, Alfred	1896
1884	*Rickard, Reuben	1896
1877	†Rickard, R. H.	1885
1872	†Ricketson, John H.	1900
1883	*Rider, W. E.	1892
1886	*Ringeling, Frank	1893
1898	*Rioseco, Pedro P.	1903
1883	*Riotte, Eugene N.	1891
1902	†Ripley, Charles O.	1905
1899	***Roberts-Austen, W. C.**	1902
1890	*Robinson, L. L.	1892
1878	*Robinson, Thomas W.	1880
1882	*Rogers, A. N.	1890
1893	*Roosevelt, Elliott	1894
1876	**Rosecrans, W. S.	1898
1871	*Rothwell, Richard P.	1901
1895	**Rotthoff, Wilhelm	1897
1900	**Sahlberg, August	1903
1882	*Santa Maria, Raymundo de	1883
1886	*Savage, E. G.	1891
1882	*Saylor, David O	1884
1892	††Schaffer, Charles	1903
1883	*Schaufuss, E. C.	1889
1872	*Schirmer, I. F. L.	1877
1891	*Schlink, T.	1893
1886	*Schmalensée, Carl von.	1887

Elected.		Died.
1883	*Schmitz, Emerich J.	1905
1882	*Schuchard, Charles	1883
1876	†Schwartz, J. E.	1900
1871	*Scranton, W. H.	1889
1888	*Seddon, T.	1896
1900	†Seeger, Ludwig	1905
1890	***Serlo, Albert**	1898
1904	*Sevier, Irving H.	1904
1893	*Seymour, L. I.	1900
1877	*Sheafer, P. W.	1891
1888	**Shields, C. O.	1896
1875	*Shinn, W. P.	1892
1881	*Sickles, T. E.	1885
1879	***Siemens, C. William**	1883
1872	*Silliman, B.	1885
1871	*Silliman, J. M.	1896
1885	*Sims, Alfred W.	1895
1902	*Sims, Wm. J.	1903
1888	*Skinner, T. L.	1894
1874	*Slade, F. J.	1891
1901	*Slavens, John H.	1904
1883	*Sluder, E. E.	1897
1880	*Smalley, W. A.	1886
1890	*Smith, Frederick H.	1899
1877	*Smith, Hamilton	1900
1875	*Smith, H. S.	1899
1894	*Smith, J. Harcourt	1899
1887	*Smith, W. T.	1898
1900	*Sperry, Jacob J.	1905
1897	*Spotswood, George McL.	1903
1889	*Spottswood, G. A.	1896
1893	*Sprow, J. H.	1895
1886	†Squier, Charles B.	1904
1889	*Stanley, Henry M.	1902
1900	*Stantial, Otis T.	1903
1872	*Steitz, Augustus	1876
1881	*Sterling, Henry S.	1882
1881	*Stetefeldt, C. A.	1896
1894	*Stevens, Andrew	1895
1899	*Stevens, Edwin A.	1902
1896	*Stevens, Wm. F.	1902
1891	*Stickney, C. Wade	1904
1881	*Stinson, John M.	1884
1874	*St. John, I. M.	1880
1885	*Stockwell, N. S.	1888
1891	*Stoddard, A. B.	1900
1886	*Stodder, R. H.	1889
1872	*Stoebling, Hermann	1875
1902	*Stoiber, Gustavus H.	1905
1890	*Stollmeyer, A. B.	1890
1884	*Stone, Gen. Charles P.	1887
1892	*Stone, G. G.	1893
1888	*Straker, Tooke	1892
1893	*Striedinger, J. H.	1894
1905	*Study, W. L.	1905
1900	*Swan, Robert M. W.	1905
1903	*Swaney, Homer H.	1904
1879	*Swindell, William	1902
1898	*Swoyer, John H.	1899
1873	*Symington, W. N.	1899
1871	*Symons, W. R.	1888
1889	*Szontagh, Oscar	1903
1900	*Taunton, F. W.	1900
1892	*Taylor, George R.	1903

Elected.		Died.
1875	*Taylor, W. J.	1903
1875	*Tefft, Walter	1885
1886	*Terhune, Richard H.	1905
1882	*Thaw, Wm., Jr.	1892
1891	*Thielen, Alexander	1897
1892	*Thiry, Joseph	1905
1871	***Thomas, David**	1882
1892	†Thomas, D. M.	1895
1871	*Thomas, John	1897
1881	*Thomas, Sidney G.	1885
1894	**Thompson, F. A.	1897
1875	*Thompson, Prof. C. O.	1885
1896	†Thompson, William T.	1899
1893	*Thomson, John L.	1900
1879	*Thonard, Leon	1886
1875	*Thurston, Robert H.	1903
1881	*Tileman, John N.	1888
1876	*Torrance, J. F.	1895
1890	*Torrey, Gray	1898
1897	*Totten, Alfred I.	1905
1878	*Tower, A.	1891
1883	*Trippel, Alexander	1896
1881	*Troilius, M.	1886
1897	*Tucker, Charles R. L.	1902
1871	***Tunner, Peter Ritter v.**	1897
1895	*Turner, Robert B.	1903
1877	*Tuttle, H. A.	1888
1886	*Tyson, James W.	1900
1890	*Ulrich, George H. F.	1900
1899	*Vale, Stephen W.	1902
1884	*Van Slooten, Wm.	1901
1887	*Van Tuyll, C. B.	1890
1888	*Van Wickle, A. S.	1898
1889	*Van Zandt, F.	1892
1880	*Veeder, H.	1896
1874	*Vezin, Henry A.	1902
1902	*Virgoe, Walter H.	1905
1891	*Wagner, J. R.	1899
1888	*Waithman, Hubert	1891
1894	*Walker, Hamilton	1895
1885	†Walker, Joseph R.	1901
1886	*Walker, W. J. B.	1894
1874	*Walsh, Edward, Jr.	1901
1884	*Walter, T. Frank	1888
1872	*Walz, Isidor	1877
1878	†Warner, L. E.	1884
1882	*Waters, J. H. E.	1893
1886	*Waters, Thomas J.	1898
1887	*Watson, Frederick M.	1900
1897	*Watson, Wm.	1902
1881	*Watts, D.	1893
1882	*Webb, H. Walter	1900
1875	*Weeks, Joseph D.	1896
1895	*Weir, Robert S.	1898
1875	*Welch, Ashbel	1882
1890	*Wellman, Charles H.	1905
1880	*Wells, Bard	1893
1875	*Wendel, Dr. A.	1881
1874	*Wendt, A. F.	1893
1888	*West, A. R.	1893
1875	*Wheatley, Charles M.	1882
1875	*Wheeler, Moses D.	1889
1882	*Wheelock, Jerome	1902
1879	†Whilldin, W. I.	1882

Elected.		Died.
1892	*Whitaker, Thomas D.	1896
1886	*White, James B.	1887
1898	*Whyte, John S.	1902
1877	*Wiestling, G. B.	1891
1885	*Wilcox, S.	1893
1888	*Williams, Frank	1901
1875	*Williams, Henry	1902
1883	*Williams, J. Francis	1891
1883	*Williams, J. J.	1892
1887	*Williams, Oliver	1904
1876	*Wilson, J. A.	1896
1887	*Wilson, J. W.	1894
1886	*Wilson, Walter B.	1904
1898	*Wister, John	1900
1871	†Witherbee, J. G.	1875
1893	*Wood, James G.	1899
1883	†Wood, W. Dewees	1899
1881	*Wood, Wm. J.	1885
1895	*Woodford, Clarence A.	1898
1879	*Worthington, H. R.	1880
1880	*Wright, Charles E.	1888
1902	*Wright, Fred A.	1903
1871	†Wright, Harrison	1885
1876	*Wrigley, H. E.	1882
1881	*Wurts, C. P.	1892
1883	*Yardley, Thomas W.	1900
1879	**Young, James B.	1902

LIST OF MEMBERS AND ASSOCIATES ARRANGED ACCORDING TO STATES AND TOWNS.

ALABAMA.

Aldrich, Aldrich, W. F. *Anniston*, Noble, A. E *Bessemer*, Fergusson, V. *Birmingham*, Aldrich, T. H., Jr., Bowron, C. E., Bowron, J., Davis, F. H., Dimmick, F. D., Hillman, Ludwig, C. P., McCarthy, M. E., McCormack, G. B., McCrery, Ramsay, E., Shook, A. M. *Ensley*, McDonald, S., Shook, J. W. *Gadsden*, Lee, R. H., Jr. *Gannts Quarry*, Hiller, E. *Helena*, Squire, J. *Huntsville*, Moss. *Lehigh*, Toulmin. *Oxmoor*, Greenamyer, A. G. *Rock Run*, Garvin, J. M. *Selma*, Saylor, B. F. A. *Sheffield*, Miller, D. I. *Tuscaloosa*, Lodge, J. *Woodward*, Woodward, A. H.

ALASKA.

Coppermount, Wiswell, H. J. *Douglas Island*, Macdonald, J. *Ellamar*, Stevens, B. *Fairbanks*, Hamilton, A. L. *Haines*, Le Wald, E. A. *Jualin*, Hoggatt, W. B. *Juneau*, Denby, Hampton, W. H., Thane, B. L., Whipple, J. R. *Ketchikan*, Barber, J. C., Parker, J. L., Reid, G. D. *Nome*, Garfield, C. D. *Snettisham*, Tisdale. *Teller*, Hirshberg, M. R. *Treadwell City*, Kinzie, Stow, H. P. *Valdez*, Esterly, G. M., Hazelet.

ARIZONA.

Basin, Carpenter, L. B. *Bisbee*, Douglas, W., Fricke, J. H., Hoatson, Parnall, S. A., Pelton, R. T., Ricketts, L. D., Sherman, G. F. G., Smith, F. W., Smith, H. A., Street, G. B., Whiteley, E. E. *Blanchard*, Murray, J. J. *Clifton*, Colquhoun, Forbes, D. L. H., Grabill, Veitch, Watson, R. B. *Congress*, Goodloe. *Crown King*, Trengrove, S. R. *Douglas*, Bowen, H. P., Fleming, E. P., Lee, G. B., Rutherford, F. *Dudleyville*, Myers, J. W. *El Tiro*, Moss, C. O. *Globe*, Berray, Emmons, N. H., 2d, Jones, E. H., Snell. *Greaterville*, Coming. *Jerome*, Clark, W. L. *Kingman*, Wallace, J. P., Wheelock, R. P. *Kofa*, Lampshire, J. O., Pomeroy, H. G. *Mayer*, Treadwell, E. D. *Morenci*, Carmichael, Clark, C. D., Honeyman, Mills, C. E., Wallace, L. R. *Naco*, Woodward, W. M. H. *Nogales*, Glore, H. G., Henley, Merwin, E. W., Sandoval, A., Sandoval, P. *Paradise*, Hoar. *Patagonia*, Lincoln, F. C., Prout, J. W., Jr., Richmond, A. B. *Phœnix*, Armstrong, T., Defty. *Prescott*, Blauvelt, H., Bunker, C. E., Claypool, W. M., Drescher, F. M., Fairbank, Haggott, E. A., Lengle, E. F., Mason, R. T., Stevens, H. W., Wilson, E. J. *Tombstone*, Gage, E. B., Staunton, Walker, E. W. *Tucson*, Blake, W. P., Burgess, De Lashmutt, McCleary, Mann, J. S. *Val Verde*, Weichsel, O. M. *Vivian*, Bretherton, G. K. *Wendeldale*, Smith, F. C.

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Fayetteville, Purdue. *Little Rock*, Fordyce. *Midland*, Denman, H. *Millville*, Glassbrook, C. I. *Perrysmith*, Smith, S. R.

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Alameda, Arents. *Amador City*, Downs, C. R., Tregloan. *Angeles Camp*, Diggles, R. N., Kennedy, C. E. *Antioch*, Belshaw. *Barstow*, Miller, C. W. *Berkeley*, Abadie, Butters, Christy, Dozier, Frazier, W. T., Hall, F. F., Haseltine, R. S., Hersam, Landfield, Lindsay, L., Mansfield, N. T., Morley, W. S., Sharwood, W. J. *Big*

Oak Flat, Dron. *Bodie*, Bradley, W. W., Hamilton, W. R., Hoover, T., Hoover, T. J., Jackson, B. N., Nutter., E., H. *Bullion*, Power, H. T. *Callahan*, Scott, E. H. *Cartero*, Hollister. *Carters*, Partz, J. L. *Chico*, Taylor, J. J. *Copperopolis*, Baird, D., Ross, G. McM. *Coyote*, Haehl, H. L. *Encinitas*, Wauchope, J. A. *Fruitvale*, Haskins, W. S. *Galt*, Harvey, F. H. *Gaston*, Bonestell, H. S. *Gazelle*, Sawyer, H., Walker, E. *Grass Valley*, Foote, A. B., Foote, A. de W., Lakenan, Nye, R. Oliver. *Gwinmine*, McClure, D., Thomas, F. F. *Haydenhill*, Collier, Geisendorfer. *Hercules*, Bermingham, J. *Ingot*, Baxter, F. K., Bretherton, S. E., Bretherton, W. B., Harms, A. *Jackson*, Detert. *Kennett*, Brown, A. H. *Keswick*, Jones, T. J., Wright, L. T. *Long Beach*, Coleman, R. P. *Los Angeles*, Booth, F., Boyle, J. L., Clark, E. M., Comstock, T. B., Dennis, F. J., Dewey, W. P., Falco, A., Fletcher, Gee, Giroux, J. L., Greene, L. H., Hart, E. G., Henne, Hooper, G. H., Krumb, Lindsay, L., Maxson, C. W., Mitchell, G., Moody, B., Mudd, S. W., Nissen, P. N., Norton, R. H., Osborne, H. Z., Perez, Plater, Poindexter, H. T., Probert, F. H., Richardson, D., Robbins, F, Schader, Schoonmaker, H., Scowden, Shannon, C. M., Siebert, F. J., Starr, C. C., Storrow, Talmage, A. A., Thompson, C. H., Williams, B., Wiseman, P., Wilson, G. B. *Los Gatos*, Owen, J. *Melones*, Langford, F. *Milton*, Williams, Lewis. *Modesta*, Sloan, C. E. *Mojave*, De Kalb, Jamison. *Mt. Bullion*, Derby, C. C., Waste, H. L., Wilkinson, J. F. *Napa*, Wartenweiler. A. *Nevada City*, Sutherland, L. A. *Oakland*, Blake, E. T., Coe, I. J., Huntley, D. B., Mills, E. C., Ropp, Selby, P. *Oroville*, Ekman, Hamlyn, Hammon, Kimball, Munro, Perry, O. C. *Palo Alto*, Allen, T., Clevenger, Edsall. *Pasadena*, Del Mar, Hope-Doeg, Lewis, C. M. *Petaluma*, Anderson, A. J. *Placerville*, Clark, G. M. *Redlands*, Pentland, W. J. *Redondo*, Bulkley, F. G., Smalley, W. W. *Riverside*, Bain, H. A., Choate, W., Pedley. *Rough and Ready*, Dikeman, J. M. *Sacramento*, Cranston, R. E. *San Francisco*, Adams, M. T., Aubury, Barber, W. B., Barbour, T. J., Benjamin, Bosch, A., Bosqui, Bradley, F. W., Brown, H. F., Brown, R. G., Brownell, Campbell, J. C., Canfield, C. L., Carr, H. C., Carrigan, Carver, L. H., Cheyney, Clark, F., Cobb, W. L., Cohen, H. A., Connor, S. B., Corbus, A. W., Corbus, J. P., Crawford, J. J., Cummins, L., Dakin, F. H., Deidesheimer, Doble, Dodd, Drum, Fisher, W. B., Fowler, E. J., Gender, Gow, Griffin, F. W., Griffin, M. E., Haas, H., Halloran, Hamilton, C. A., Hanks, Hart, R. G., Harvey, H. H., Heller, Howard K., Hunt, B., Innes, Janin, L., Jost, Keyes, W. S., King, L. M., Kipp, Knox, N. B., Lamb, M. R., Leffingwell, Lindley, McClintock, W. H., Maxwell, Melliss, Miller, H. E., Miller, W. P., Jr., Morris, F. L., Myrick, Newman, Noyes, W. S., Paymal, G. W., Perry, O. B., Pomeroy, W. A., Postlethwaite, Preston, Price, Radford, Ralston, Raymond, S. S., Requa, Richards, H. de C., Rickard, E., Rix, Rogers, A. P., Roote, Rosenfeld, Schorr, Scrutton, Searles D., Simonds, E. H., Smith, H. D., Spiers, Stebbins, E. W., Storms, W. H., Thomas, J. A., Thurston, E. C., Turner, R. C., Voorhis, E. C., Wagoner, Wartenweiler, Weck, Wepfer, G. W., Wiel, S. C., Willson, F. E., Wiseman, P., Wright, W. Q., Yard, Young, W. H. *San Diego*, Cliff, Fremersdorf, Jenks, A. W., Playter, H., Van Cleve, C. McK. *San José*, Cornish, H. L. *Santa Barbara*, Austin, J. B., Johnston, F. L., Thomas, C. A. *Santa Paula*, Hardison. *Santa Monica*, Rathburne, M. R. W. *Sausalito*, Wyatt, J. S. *Selby*, Nichols, H. B. *Serad Valley*, Grider. *Sonora*, Hopper, Skewes, E. *Soulsbyville*, Huston, Scott, W. G. *Stanford University*, Branner, Newsom. *Stedman*, Darlington, W. *Stent*, Kerr, M. B. *Sunnyvale*, McChrystal, J. H. *Sutter Creek*, Downs, W. E., Ross, J., Jr. *Thebe*, Wrinkle, L. F. J. *Van Trent*, Burnand, A. A. *Visalia*, Small, G. W. *Winthrop*, Hanley, H. R., Keating, Muir, D.

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Anaconda, Hawkins, J. T. *Apex*, Smillie, S. *Argo*, Pearce, H. V. *Aspen*, Bardwell, Hall, N. G., Hallett, S. J., Hare, Woodward, H. E. *Boulder*, George, R. D., Harlow. *Breckenridge*, Evans, G. H., Revett. *Buena Vista*, Eyre, W. P. *Camp Bird*, Harris, W. F. *Canon City*, Burrage, W. H., Jackling. *Cedar Creek*, Knowles. *Central City*, Fleschhutz. *Colorado Springs*, Bolles, J. H., Cannon, R. M., Cowan, J. L., Finlay, Gilpin, Hawkins, J. D., Hewett, G. C., Keener, G. L., King, H. E., MacNeill, Ritter, E. A., Shapleigh, R. W., Strieby, Tod, Van Diest, E. C., Wackenhut, G. J. *Cripple Creek*, Arthur, Colwell, A. B., Hills, Johnson, R. I., Starkweather, Willis, F. G. *Denver*, Abbott, J. W., Alexander, G. E., Argall, P., Bancroft, Bayles, Beatty, Boehmer, Bosco, Bowden, J. E., Brandes, Brunton, Bulkley, F., Burlingame, E. E., Burlingame, W. E., Campbell, F. J., Carpenter, F., Carpenter, F. R., Cazin, Chase, E. E., Chauvenet, R., Clerc, Cohen, L., Collins, G. E., Comstock, C. W., Crewe, L. C., Crow, Cunningham, P. H., Darby, T. L., Davis, W. C., Dewey, C. E., Doveton, Dumont, Durell, Dwelle, J. E., Edwards, J. W., Engelhardt, Farish, Finch, J. W., Foster, E. L. N., Foster, G. C., Foucar, Frank, H. L., Freeland, F. T., Garvin, C. J., Gates, Gilchrist, J. D., Godshall, L. D., Gouyard, Grant, J. B., Grant, R. J., Gross, Guiterman, Hardinge, Hastings, Hawkins, E. N., Hearne, F. J., Hopkins, J. F., Howe-Carpenter, Hughes, C. J., Jr., Izett, Johnson, A. E., Johnston, F., Jones, E. B., Kelley, W. A., Kennedy, G. A., Lakes, A., Lee, E. A., Lowe, McClurg, J. A., McEwen, S., Malins, F. A., Mills, W. F. R., Mildron, R. B., Minard, Moore, C. J., Morley, F. H., Nagel, H. P., Jr., Nesmith, Noble, L. S., Norman, Orr, W., Page, W. B., Palmer, E. V., Parker, R. A., Patterson, G. H., Pattison, Pearce, R., Porter, J. A., Pritchett, Raht, Rainsford, R. S., Richards, J. W., Rickard, F., Robeson, J. H., Royer, Sanderson, Sayre, Schroter, G. A., Schwarz, T. E., Scobey, J. C., Sebben, Sessinghaus, Shaffer, E. L., Shepard, F. E., Shipman, H. A., Skinner, E. N., Skinner, J. C., Smith, E. A., Jr., Snedaker, Sperry, E. A., Stearns, T. B., Swart, Taft, H. H., Taylor, F. M., Thomas, K., Throckmorton, Titcomb, Titsworth, Traylor, J. A., Turner, J. K., Vaile, Weed, F., Wilson, J. A., Wood, L. S., Woodbridge, T. R., Woodrow, J. W., Wuensch. *Dewey*, Irwin. *Dillion*, Thorne, W. E. *Dorchester*, Forsyth, A. *Durango*, Clemens. *Edgewater*, Devinny. *Empire*, Roepper, F. A. *Erie*, Gorder. *Eureka*, Hanson. *Florence*, Danforth. *Fort Lupton*, Davis, F. S. *Georgetown*, Tingle, Vidler, L. W., Vidler, R. C. *Golden*, Liddell, T. P., Traphagen, Young, L. E. *Grand Junction*, Edwards, H. W., Nichols, J. C. *Idaho Springs*, Barbour, P. P., Brownlee, A. G., Haggott, W. A., Kimball, G. K., Jr., May, J. J., Mixsell, P., Morton, Nicolson, G. W., Renshaw, Stumm, Underhill, Wiley, W. H. *Independence*, Thomas, E. G. *Ironton*, Downer, R. H. *Jamestown*, Brown, A. H. *Leadville*, Carnahan, C. T., Roeser, Webb, W. M., Wood, T. S. *Mancos*, Toll, R. H. *Ouray*, Brinker, A. C., Carney, H. J., Cox, W. J., Franck, A. C., Goodale, S. L., Hurlburt, Newhall, C. S., Thomas, C. S. *Pitkin*, Toll, A. H. *Pueblo*, Child, A. T., Hogarty, B., Howard, W. H., Kilburn, W. D., Rhodes, F. B. F., Robinson, C. S., Rose, C. R., Stoiber, E. G. *Redstone*, Osgood, J. C. *Silverton*, Cox, W. R., Dyson, J., Guess, H. A., Harrison, A. W., Hollis, R. W., Holt, M. B., Hurley, T. J., Kane, Stoiber, L. A., Walter, E. W. *Sunshine*, Healey, A. E. *Telluride*, Anderson, M. L., Carhart, Chase, C. A., Gilkerson, H. G., Herron, Holland, Lay, Lindsley, H., Townsend, A. R., Wolf, H. J. *Trinidad*, Plumb, C. H., Sterling, R. R. *Victor*, Becker, T., Bodfish, Burdick, Church, M. J., Eads, Johnson, O., Kurie, Sheldon, T. H., Smale, F. L., Valentine, M. R., Williams, F. T., Woods, F. M.

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Ansonia, Farrel, F. *Branford*, Hammer, A. E. *Bridgeport*, Ferry, C., Somers, Sperry, E. S. *Danbury*, Buck, V. B. *Hartford*, Souther, H. *New Haven*, Du Bois, A. J., Huntoon, Russell, E. H., Tillson, B. F., Tyler, V. M., Wells, H. L., Whitney, E., Jr. *Ridgefield*, King, R. H. *Torrington*, Bassett, W. H. *Wallingford*, Canby, R. C. *Waterbury*, Goss. *West Haven*, Nason.

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Wilmington, Barksdale, Du Pont, Griffiths, H. B., Haskell, H. G.

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L., Speer, J. R., Speller, F. N., Stevenson, M. R., Taylor, E. J., Taylor, S. A., Walter, B., Weber, F. C., Westinghouse, Wilkins, W. G., Willard, J. O., Wood, G. R., Wood, T. D. *Pittston*, Law. *Port Carbon*, Allison, R. *Pottstown*, Cook, E. S., Hartshorne, Potts, G. H., Roe. *Pottsville*, Althouse, Beale, Ginder, W. H. H., Herndon, Luther, E. C., Richards, W. J., Sheafer, A. W., Sheafer, W. L., Thompson, H. S. *Primos*, Stein. *Punxsutawney*, McLeavy, J., Sims, H. N. *Reading*, Bower, C. P., Clymer, F. H., McIlvain, W. R., Pendleton, J. S., Quier, E. A., Sargent, G. W., Smink. *Riddlesburg*, Lauder, W. *Robesonia*, Patterson, S. B. *Sandy Run*, Leisenring, W. *Scranton*, Archbald, J., Belin, Davis, M., Jr., Foster, R. J., Fuller, E. L., Jones, E. S., Lawrence, W. L., Mattes, C. C., Mattes, W. F., Of, C., Parke, Platt, F. E., Richmond, W. H., Scranton, W. W., Sherrerd, A. H., Simpson, C. D., Stoek, Sturges, C. B., Taylor, W. H., Wolf, T. 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C. *La Paz*, Fletcher, L. F. *Las Esperanzas*, Jones, E. R., Ludlow, E. *Linares*, Self. *Llano*, Austin, A. M. *Magdalena*, Baumgarten, Fitch, F., Pearce, S. H. *Mapimi*, Hamilton, F. C., Hauber, Heberlein, Riedt, Small, H. B. *Matehuala*, Dingwall., Waters, A. L. *Merelia*, Ambrosius, J. R. *Mexico City*, Aldasoro, Anderson, R. H., Arozarena, Boyd, F. J., Braschi, Briggs, R. E., Brown, W. F., Carpenter, A. B., Chevrillon, Chippendale, Collins, H. F., Dieffenbach, Du Bois, E., Espinosa, Fisher, L. F., Garcia, Graham, W. W., Graves, McD., Helm, Hochschild, Kleinschmidt, Lukis, McCann, McGrath, J., Ordonez, Parker, C. F., Phillips, J. L., Ryder, Sellevier, C., Smit, E., Smith, E. A., Spence, G., Stadelmann, G., Truax, S. *Miñaca*, Hardy, J. G., Willey, H. I. *Minas Nuevas*, Grave, E. *Monclova*, Buck, A. H. *Monterey*, Brewer, A. K., Bridge, Carnahan, J. S., Fairchild, S. A., Hernandez, Howe, E., Jewett, E. C, Knight, E. C., Maiz, J., Palacios, Ramos, Randall, H. B. S., Tarnava, Tuschka, Wilson, N. R., Zambrano. *Nadadores*, Fuente. *Nogales*, Bonillas. *Oaxaca*, Adams, H., Brill, Clark, M., McCurdy, J. E., Watts, W. L., Woolrich, A. H. *Ocampo*, Flynn, Hackett, Leese, Thompson, W. *Ocotlan*, Hamilton, C. A. *Ojuela*, McLintock, A., Weniger, R., Whitaker, O. R. *Orizaba*, Stacpoole, S. W. *Otto*, Platt, E. H. *Pachuca*, Alatorre, R. F., Girault, Grothe, Landero, Solomon, T., Waters, S. *Papantla*, Payne, A. C. *Parral*, Bradley, D. H., Burr, Garcia, E., Hyslop, J. E., Keller, C. H., Levings, G. V. B., Long, J. I., MacFarlane, R. W., Robertson, P. W. K., Simpson, G. C., Wilding, J., Jr. *Peregrina*, Ryan, E. P. *Pinos Altos*, Swain, S. R., Thomson, E. *Promontorio*, Wilson, G. *Pueblo Nuevo*, Adams, W. C. *Quimichis*, Gomez, P. *Ramos*, Sistermans, F. H. *Rodeo*, Kedzie. *Sahnayacan*, Hackett, W. H. *Saltillo*, Liliendahl, Rodriguez. *San Demas*, Gage, E. C., Kirk, R. C., Rawlings. *San Fernando*, Sanders, J., Smith, C. A. *San Felipe*, de Rilly. *San José*, Burne, C. A. *San José de Gracia*, Tays, E. A. H. *San Luis Potosí*, Alexander, W. C., Brown, D. C., Budrow, L. R., Cuevas, Dixon, A. G., Holt, T., Hopkins, E., Ipina, Koelle, Martinez, Sistermans, Taylor, F. W. *San Miquel del Mezquital*, Williams, D. V. A. *San Nicolos del Oro*, Miller, J. W. *Santa Barbara*, Ayton, E. F., Emery, Rose, H., Swanquist, G. A. *Santa Rosalia*, Bohn, C. A. *Santa Rosalia Camaigo*, Soest, W. E. *Saric*, Wallace, H. V. *Sierra Mojada*, Hagemann. *Sultepec*, Vivian, G. G. *Talea*, Jeffrey. *Tecalitlan*, Stewart, A. J. *Teniosachic*, McLaughlin, H. M., Webster, E. H. *Tepehuanes*, Merton. *Teziutlan*, Raymond, P. A. *Tlalpujahua*, Schiertz, F. A. *Topia*, Lawrence, T. J. *Torreon*, Garza-Aldape, Hambleton, Harms, Polkinhorn, E. J. *Torres*, Bassett, T. B., Kline, Leslie, R. R., McCarty, G. J., Pomeroy, W. E. *Triunfo*, MacDonald, J. J., Nahl, A. C. *Tultenango*, Allan, T. A. *Ures*, Wendler, H. *Urique*, Nesbitt. *Vacos*, Longmaid. *Velardeña*, Drury, W. M., Rone, L. A., Stull, J. W. *Villaldama*, Foster, F. J., Robertson, J. D. *Zacatecas*, Coxe, C. E., Gmelin, E., Ragaz, I., Rickard, H.

CENTRAL AMERICA.

Costa Rica, *Mirimar,* Mann, W. S. *Puntarenas,* Crespi, Yonge. **Honduras,** *Balize,* Burchell. *San Juancinto,* Montis, de E., Nagel, F. J. Weddle. **Nicaragua,** *Bluefields,* Stanford, R. B. **Panama,** *City of Panama,* Hall, G. **San Salvador,** *Santa Rosa,* Wells, F. B.

CUBA.

Daiquiri, Holmes, E. M., Pfeiffer, Sloat, F., Whitaker, DeB. *Matanzas,* Polledo. *Santiago de Cuba,* Aguilera, Chibas, E. J., Chibas, L. F., Cox, J. S., Jr., Emerson, Miller, E. T., Yung.

DUTCH WEST INDIES.

Aruela Island, Woolmer, H. C. T.

SOUTH AMERICA.

Argentine Republic, *Villa Mercedes,* Boggs. **Bolivia,** *La Paz,* Armas, Germann, Sinn. *Potosi,* Maurice. **Brazil,** *Bahia,* Nack, C. *Minas Geraes,* Chalmers, G., Lustosa, Miller, J., Pires, Rickard, A. J. *Rio de Janeiro,* Lisboa, Miranda, J. *Rio Grande do Sul,* Scheffler, F. G. *Sao Paulo,* Derby, O. A. **British Guiana,** *Georgetown,* Bradley, R. R., Chisholm, J., Linck, F. W. **Chili,** *Copiapo,* Fergie, G., Holberton. *Graneros,* Braden, W. Hamilton, T. M., McCan, E. K. *Valparaiso,* Dorion, Loram, MacNutt. **Colombia,** *Barranquilla,* Scott, C. C. A. *Buena Ventura,* Kirkcaldy. *Cali,* Holman. *Cana,* Veatch. *Honda,* Evans, H. A., Russell, A. J. *Medellin,* Posada, Snover, G. R. *Puerto Berrio,* Tilly, A. *Quibdo,* Granger, H. G. **Dutch Guiana,** *Paramaribo,* Mayo. **Ecuador,** *Guayaquil,* Chapman, J. E., Fraser, J. H., Staver, Van Isschot, Williams, R. B. **Peru,** *Agrequipa,* Fox, A. J. *Cerro de Pasco,* Abbott, A. A., Emlaw, H. S., Kuehn, Murray, H. T., Neel, C. B., Sample, C. C. *Lima,* Adams, G. I., Balta, Bennet, T. A., Elguera, Figari, Fuchs, Letts, Reed, D. C. *Tirapata,* Dougherty, E. S.

ENGLAND.

Abergavenny, Martin, E. P. *Bedford,* Barber, G. M. *Birmingham,* Fergusson, H. B., Redmayne. *Black Pool,* Settle, J. B. *Bournemouth,* Waugh. *Brassington,* Breakell. *Brislington,* Pridham, H. *Bulcote,* Goddard. *Camborne,* Rich, W., Vivian, G. T. *Carlisle,* Bailey, E. T. *Chapeltown,* Burnham, M. H. *Chertsey,* Dudgeon. *Chesterfield,* Pilkington. *Chiswick,* Hooker, B. *Darwen,* Holgate. *Dudley,* Hughes, H. W. *Headingley,* Pullon. *Hexham,* Wrightson, W. I. *Ipstones,* Boucher. *Liverpool,* Hanckel, Pearson, J. E. *London,* Addie, R., Alabester, Atherton, T. W. T., Attwood, Austin, K., Barnett, W. J., Barney, Bayliss, Benson, Bird, R. M., Bonwick, E. W., Boorne, Borrow, F. K., Botsford, Broad, Browne, R. E., Carr, P. E. O., Carroll, Cautley, A. O., Chaplin, G. P., Charleton, Chester, Claudet, A. C., Cooke, L. H., Crane, G. A., Currie, D., Dane, Davy, Dawson, T. L., Ellis, R. W., Fairbairn, Fawcett, J. H., Feldtmann, Fell, Finch, H. W., Foster, P. L., Francis, G. G., Frecheville, R. J., Frecheville, W., Gilchrist, P. C., Gordon, J., Griffin, H. M., Griffiths, A. P., Griffiths, J. N., Halse, Henderson, J. A. L., Heneage, Hinman, Hooper, E., Hoover, H. C., Hughes, A. D., Irvine, James, A., James, J. H. C., Janin, H., Jones, C. H., Johnson, R. R., Johnston, R. B., Kennedy, N., Kingston, C. B., Lawson, J. C. E., Leckie, R. G., Leggett, Little, A., Llewellyn, Lloyd, G. H., Louis, D. A., Lund, MacArthur, J. S., Marriott, H. F., McCarthy, E. T., McDermott, McDonald, J. A., McKillop, MacKinnon, Maitland, G. C., Means, J.

H., Merricks, Morris, F. H., Nicolaus, Palmer, R. E., Paterson, E. A., Pearsall, Pearse, A. L., Peile, Prichard, W. A., Pringle, R., Reischbach, Ridge, H. M., Rolker, Sahlin, Samwell, Sandberg, Scott, F. B., Scott, H. K., Scrutton, T. C., Seal, Selkirk, W., Shockley, W. H., Sleeman, H. R., Stewart, A., Stoddart, Taylor, P., Thomae, Thomas, W. R., Thompson, W., Tom, I., Touzeau, Van Ness, Varden, Wagner, H. R., Webb, H. H., Weinberg, E. A., Western, C. R., Western, F., Whitworth, S., Wilkinson, A., Wilkinson, W. F., Williams, F., Willis, A. B., Wingate, Wood, R. A., Yorke, Young, J. W., Young, J. W. R. *Merton Park*, Turney. *Middlesboro-on-Tees*, Hawdon. *Middlesborough*, Bell, C. L., Stead, Talbot, B. *Newark on Trent*, Morris, J. *Newcastle on Tyne*, Louis, H. *Newquay*, Clemes. *Northallerton*, Brown, D. P. *Ongar*, Fielding, C. W. *Pontywain*, Bullen, J. *Port Clarence*, Johnson, W. L. *Redruth*, Dabb, C. E., Provis. *Rotherham*, Steel, H. *Seaham Harbour*, Wood, E. S. *St. Austell*, Hodge, A. *St. Leonard's on Sea*, Cragoe. *Sheffield*, Hadfield, Hardwick. *Shillingstone*, Forbes, D. G. *South Kensington*, Hunter, Jones, O. *Surbiton*, Barnado, W. S. *Tavistock*, Daw. *Totnes*, Chenhall. *Waybridge*, Pettit, A. E. *West Hartlepool*, Thomlinson.

IRELAND.

Allihies, Harris, H. J. *Dublin*, Pollok.

SCOTLAND.

Edinburgh, Balfour, J. F., Simpson, J. C. *Glasgow*, Caldwell, W. A., Crookston, Dempster, McConnell, Sawers. *Leven*, Barker, H. A. *Neuck*, Murdoch, J. V. B. *Tranent*, Burt A.

WALES.

Aberdare, Lewis, W. T. *Brymbo*, Hollings. *Cardiff*, Brown, T. F., Reese. *Portmadoc*, Andrewes. *Swansea*, Hopkins, G. V.

AUSTRIA.

Leoben, Hoefer, H.

BELGIUM.

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BOHEMIA.

Zwestow Wottitz, Wallis, H. B.

FRANCE.

Orthez, Frossard. *Paris*, Arnaud, Batz, Bel, le Bret, Cardozo, Chambost, P., Collin, Delrez, Eissler, Fevre, Garfield, A. S., Gennes, Hébert, Knoertzer, Le Chatelier, Ledoux, F. A., Levat, Osmond, Pelatan, P., Pourcel, Powel, G. H., Richards, E., Riviere, G., Robellaz, Strap, G., Würgler. *Pau*, Goupillière.

GERMANY.

Aachen, Borchers, Schwemann, A., Wust, F. *Altenessen*, Krabler. *Apolda*, Hahn. *Berlin*, Martin, A. A., Wedding, Wolff. *Bleicherode a Harz*, Vogelsang. *Bochum*, Heise. *Coblenz*, Oswald. *Düsseldorf*, Pauli, H., Schroedter. *Essen am Ruhr*, Engel. *Frankfurt*, DeNeufville, Dyckerhoff, Naumann. *Freiberg*, Schiffner, C. *Giessen*, Schiechel. *Göttleborn*, Stahler. *Hartz*, Doeltz. *Hayingen*, Wendel. *Luxembourg*, Bettendorf. *Mainz*, Heberlein, M. *Neumühl*, Grillo. *Remscheid*, Mannesmann. *Siegen*, Macco. *Silberhutte*, Havard. *Stuttgart*, Hundeshagen. *Völkingen*, Roching, H. *Wiesbaden*, Massenez.

ITALY.

Boccheggiano, Marengo, P. *Grosseto*, Cerrina-Feroni. *Lecco*, Redaelli, P. *Piedimulere*, Bordeaux. *Portoferraio*, Gleim, F. *Porto Ferrajo*, Hennin. *Savona*, Fera, C.

NORWAY.

Finmarken, Ashmore, E. P.

PORTUGAL.

Mertola, Wilbraham. *San Domingos*, Camphuis, G. A., Fane, H. W.

RUSSIA.

Baku, Fegraeus. *Moscow*, Jabs. *St. Petersburg*, Mitinsky, Tschernoff. *Batoum, South Russia*, Van Liew, W. R.

SPAIN.

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SWEDEN.

Bofors, Wykander, B. E. *Falun*, Wallin, G. *Karrgrufven*, Gränstrom. *Kiruna*, Lundbohm. *Sandviken*, Göransson. *Stockholm*, Åkerman, Berg, Bildt, Brinnell, Carlsson, H., Petersson, G. W., Sjögren, H. *Striberg*, Larson, A., Larsson. *Westervik*, Tillberg.

SWITZERLAND.

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TURKEY.

Constantinople, Whittall.

ASIA.

China, *Peking*, Kwang Kwong Yung, Willis, B. *Shanghai*, Cole, F. L., Jadot, J., Kow. *Tientsin*, Drake, N. F., Jessup, A. E. *Tong Shan*, Woo. **Dutch East Indies,** *Batavia*, Schmiedell. *Sarawak*, Young, H. S. **India,** *Bangalore*, Smeeth, W. F. *Bengal*, Agabeg. *Bombay*, Weld. *Calcutta*, Doyle, P. *Champion Reef*, Cooke, H. M. A., Jolly. *Coromandel*, Osborn, H. H. *Duff*, Bannon, H. C. *Kamptee*, Sanders, A. D. *Mandalay*, Freymuth. *Marikuppam*, Leslie, Pritchard. *Oorgaum*, Cosens, Patterson, G. A., Richards, T., Smith, P. B. **Japan,** *Chikugo*, Kuroda, Takagi, K. *Hagi*, Tsuno. *Kahogori*, Kawai, Y. *Kamaishi*, Yokoyama, C. *Katsunogun*, Takeda, K. *Kobe*, Taylor, A. W. *Kyoto*, Abe. *Sapporo*, Oshima. *Shidzuoka City*, Nishio. *Tajima-Nokuni*, Iioka. *Tokio*, Adachi, Dan, Kada, Kondo, McGregor, J. M., Makita, Sakikawa, Yamanuchi. *Yawata*, Imaizumi, K. *Yokohama*, Benneville, Williamson, H. D. *Yvichigun*, Kanda. **Korea.** *Chemulpo*, Mills, E. W. *Chinampo*, Kaeding. *Gwendoline*, Holloway, W. S. *Seoul*, Collbran, Weigall, A. R. **Persia,** *Ahwas*, Reynolds, G. B. **Siam,** *Singora*, Heal. **Siberia,** *Akmolinsk*, Agnew, F. V., Mussen, H. W. *Vladivostock*, Kousnetzoff. **Straits Settlements,** *Gopeng, Perak*, Thomson, E. D. H. *Ipoh, Perak*, Osborne, F. D. *Singapore*, Deverell, L. C., Marriner, J. T., Morris, J. F., Pearce, R. F., Simons, A. J. *Tanjong Malim*, Proust, R.

AFRICA.

Cape Colony, *Oyphegat*, Blandy, S. H. B. **Central Africa,** *Sudan*, Winmill, H. **Egypt,** *Cairo*, Stewart, P. C. A. **South Africa,** *Kimberley*, Dickinson, H. T., Nichol, W. Williams, A. F. **Matabeleland,** *Francistown,* Temby, E. T. **Natal,** *Vryheid,* Netter, A. J. **Orange River Colony,** *Jagersfontain,* Early. *Vredeport,* Lawrence, H. L. **Rhodesia,** *Bulawayo,* Chalmers, J. A., Currie, Durant, Garthwaite, Jones, H. E., Ludlow, L., Parker, J. E., Pringle, H. A., Whitmore. *Gulong,* Chennells. *Selukwe,* Little, J. B. **Transvaal,** *Benoni,* Way. *Beerlaagte,* Stanley, J. *Cleveland,* Hancock, S., Murray, F. D. *East Rand,* Berry, J. F., Hellman, Horst, Mathews, F. W., Nis, Stephens, F. B., Vaux, C. A., Wilson, N. *Eureka,* Metcalf, A. T., Stacpoole, A. R. *Florida,* Stockett, A. *Germiston,* Cameron, Gazzam, Reading, R. W. *Johannesburg,* Behr, Brett, A. J., Britten, Bottomley, Bradford, W., Bruce, T. C., Bushell, B. D., Caldecott, Calderwood, Carter, B. P., Carter, T. L., Catlin, R. M., Cohen, E. H. A., Collings, Collins, W. J., Denny, G. A., Denny, H. S., Drake, F. M., Ekberg, Frames, M. E., Gordon, W. D., Grey, Griffiths, H. D., Hatch, Hebbard, A., Henderson, J. McC., Honnold, W. L., Hughes, H., Ingram, H. E., Jennings, S. J., Johns, J. H., Johns, T. E., Kehler, Knecht, Lawn, Lee, M. P., Mason, J. G., Mein, W. W., Park, W. E., Payne, H. G., Recknagel, Robeson, Rusden, A. G., Short, Stark, Symons, Teale, Temby, Thomson, S. C. Townsend, H. P., Voskule, G. A., Warriner, R. C., Wheler, A. S., Wilkinson, D., Williams, J. R., Wulff. *Knights,* Hay, H., Prout Womble, L. A. *Krugersdorp,* Davis C. R., Strout E. A, *Luipards Vlei,* Carter, T. L. *Mariasburg,* Lewis, F. B. *Pilgrim's Rest,* Brown, W. S., Neale, A. L. *Potchefstroom,* Judge, A. T. *Pretoria,* Andrew, T. *Roodeport,* Piddington, F. L., Skinner, H. R. *Springs,* Sharwood, W. S. *Wolvehoek,* Park, M. **West Africa,** *Ayeinm,* Young, J.S. *Dunkwa,* Dixon, J. T. *Sekondi,* Cosby, R. P. *Tarkwa,* Bensusan.

AUSTRALIA.

New South Wales, *Boppy Mountain,* Williamson, W. D. *Broken Hill,* Cunningham, J. C., Delprat, Gregson, Godfrey, J. R., Hebbard, J., Horwood, Lindsay, J. A. M., Low, Palmer, T. H., Sweet, T. G., Wainwright, W. E., Weir, G. *Burraga,* Corbould, Dyson, T. I. *Cadia,* Brook, H. E. C. *Cobar,* Gould, H. J., Polkinghorne, J. *Cockle Creek,* Morse, P. S., Moulden. *Dapto,* Burrows, C. W. *Forbes,* Dunstan, A. J., Stephen, A. E. *Lithgow,* Blakemore, G. H., Longworth, W. *Milsons Point,* Robertson, J. R. M. *Neroigunoah,* Warn, J. E. *Nundle,* Crichton. *Nyamagee,* Taylor, J. *Salisbury,* Bloomfield, A. L. *Shuttleton,* Armstrong. J. O. *Sydney,* Freeman, A. W., Helms, Howell, J., Jarman, Lempriere, O. T., Mingaye, Orr, A., Paul, F. P., Power, F. D., Read, R., Scheidel, Shallcross, V. F., Smith, G , Taylor, A. J. *Tent Hill,* Reid, J. H. *Woolwich,* Mackenzie, G. S. **North Australia,** *Port Darwin,* Grace, W. F., Wilson, C. H. **Queensland,** *Charters Towers,* MacLeod, W. A., Poole, W., Russell, M. *Chillagoe,* Gibb, A., Greenway, Mainwaring, Moule, J. W. *Georgetown,* Maxwell, W. *Irvinbank,* Moffat, J. *Mount Garnet.* Valentine, C. F. *Mount Morgan,* Du Faur, Richard, G A., Seale, H. P., Wentworth, White, N. F., Wilson, J. B. *Ravenswood,* Phillpotts, W. M. *Stannary Hills,* Gipps, F. de V., Raleigh, J. R. *Stanthorpe,* Hall, E. **South Australia,** *Adelaide,* Ayers, Grundy, E. L., Hawker, Miller, J. *Gawler,* Fergusson, J., Martin, J. F., Pearson, J. F., Wesley, J. A. B. *Moonta Mines,* Hancock, H. L. *Port Pirie,* Jobson, Poage. **Victoria,** *Ballarat,* Dawbarn, G. J., Smith, A. M. *Baringhup,* Granstedt, F. H. *Cassilis,* Mosley. *Elsternwick,* Savage, A. E. *Maryborough,* Doepel. *Melbourne,* Black, Brown, A. T., Chapman, C. W., Courtney, Daly, Dickenson, Grayson, Hartrick, Herzig, C. S., Higgins, Knox, W., Mackay, P. A., Nicholas, Noyes, H., Odling, Saddler, Schlapp, Wilson, H. *Tongio,* Avery, J. **Western Australia,** *Bonnievale,* Lidgey, E. *Boulder,* Aarons, Fraser, A., Hamilton, R., Nardin, E. W., Nicolson, R. B., Sutherland, J. W. *Broad Arrow*, Williams, R. M. *Coolgardie*, Thomas, A. E. *Cooya Pooya Station*, Wittenoom, C. H. *Freemantle*, Klug. *Kalgoorlie*, Bigelow, D. E., Cleland, E. D., Cobbe, H. N. G., Edols, Gibson, R., Loring, Macgeorge, Roberts, G. M., Robertson, H. P., Rogers, C. E., Sharp, W. G., Ward, O. B., Whitfield, H. E. *Kookynie*, Robinson, R. *Leonora*, Diggles, J. A. *Mensies*, Greenard, W. F., Rayfield. *Mertondale*, Judd. *Mount Malcolm*, Turner, W. J. *Mt. Sir Samuel*, Vail, H. E. *Perth*, Allen, R., Montgomery, Simpson, E. S., Watkins, A. *Southern Cross*, Watson, C. S.

NEW ZEALAND.

Auckland, Gordon, H. A., Rich, F. A., Rhodes, C. *Dunedin*, Allen, Jas., Beal, Park, J., Smith, J. P. *Hamilton*, Graham, K. M. *Karangahake*, Stansfield, H. *Komata*, Brown, F. C. *Lawrence*, Jackson, J. H. *Oamaru*, Don. *Tararu*, Powell, R. W. *Waihi*, Banks, E. G., Evered, N. J., Williams, R. E. *Waikumete*, Hosking, G. F. C., Rosewarne, D. D. *Wellington*, Bell, J. M., Seddon, R. J.

TASMANIA.

Beaconsfield, Boyd, T. M., Heathcote, More, G. A. *Derby*, Bell, S. C. N., Clark, L. C., Clouston. *Gormanston*, Batchelor, W. T. *Hobart*, Kennedy, J., Smith, R. N. *Launceston*, Brown, R. M., King, E. M., Millen, J. D., Simson, Thompson, L. G., Tulloch. *Moonah*, Williams, L. *Mount Read*, Thow. *North Lyell*, Smith, G. O. *Queenstown*, Dean, A. L., Sticht, R. C., Waller, G. A., Wesley. *Waratah*, Kayser, H. W. F. *Zeehan*, Briggs, W. A. J., Levings, J. H., Marks, M. M., Quartano, P., Reid, F. W., Sale, W. R., Waller, R. F.

LIST OF THE MEETINGS OF THE INSTITUTE AND THEIR LOCALITIES FROM ITS ORGANIZATION TO OCTOBER, 1904.

			Transactions.	
Number.	Place.	Date.	Vol.	Page
I.	Wilkes-Barre, Pa.*	May, 1871	i.	3
II.	Bethlehem, Pa.	August, 1871	i.	10
III.	Troy, N. Y.	November, 1871	i.	13
IV.	Philadelphia, Pa.	February, 1872	i.	17
V.	New York, N. Y.*	May, 1872	i.	20
VI.	Pittsburg, Pa.	October, 1872	i.	25
VII.	Boston, Mass.	February, 1873	i.	28
VIII.	Philadelphia, Pa.*	May, 1873	ii.	3
IX.	Easton, Pa.	October, 1873	ii.	7
X.	New York, N. Y.	February, 1874	ii.	11
XI.	St. Louis, Mo.*	May, 1874	iii.	3
XII.	Hazleton, Pa.	October, 1874	iii.	8
XIII.	New Haven, Conn.	February, 1875	iii.	15
XIV.	Dover, N. J.*	May, 1875	iv.	3
XV.	Cleveland, O.	October, 1875	iv.	9
XVI.	Washington, D. C.	February, 1876	iv.	18
XVII.	Philadelphia, Pa.†	June, 1876,	v.	3
XVIII.	Philadelphia, Pa.	October, 1876	v.	19
XIX.	New York, N. Y.	February, 1877	v.	27
XX.	Wilkes-Barre, Pa.*	May, 1877	vi.	3
XXI.	Amenia, N. Y.	October, 1877	vi.	10
XXII.	Philadelphia, Pa.	February, 1878	vi.	18
XXIII.	Chattanooga, Tenn.*	May, 1878	vii.	3
XXIV.	Lake George, N. Y.	October, 1878	vii.	103
XXV.	Baltimore, Md.*	February, 1879	vii.	217
XXVI.	Pittsburg, Pa.	May, 1879	viii.	3
XXVII.	Montreal, Canada	September, 1879	viii.	121
XXVIII.	New York, N. Y.*	February, 1880	viii.	275
XXIX.	Lake Superior, Mich.	August, 1880	ix.	1
XXX.	Philadelphia, Pa.*	February, 1881	ix.	275
XXXI.	Staunton, Va.	May, 1881	x.	1
XXXII.	Harrisburg, Pa.	October, 1881	x.	119
XXXIII.	Washington, D. C.*	February, 1882	x.	225
XXXIV.	Denver, Col.	August, 1882	xi.	1
XXXV.	Boston, Mass.*	February, 1883	xi.	217
XXXVI.	Roanoke, Va.	June, 1883	xii.	3
XXXVII.	Troy, N. Y.	October, 1883	xii.	175
XXXVIII.	Cincinnati, O.*	February, 1884	xii.	447
XXXIX.	Chicago, Ill.	May, 1884	xiii.	1
XL.	Philadelphia, Pa.	September, 1884	xiii.	285
XLI.	New York, N. Y.*	February, 1885	xiii.	585

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* Annual meeting for the election of officers. The rules were amended at the Chattanooga meeting, May, 1878, changing the annual election from May to February.

† Begun in May at Easton, Pa., for the election of officers, and adjourned to Philadelphia.

Number.	Place.	Date.	Transactions. Vol.	Transactions. Page
XLII.	Chattanooga, Tenn.	May, 1885.	xiv.	1
XLIII.	Halifax, N. S.	September, 1885.	xiv.	307
XLIV.	Pittsburg, Pa.*	February, 1886.	xiv.	587
XLV.	Bethlehem, Pa.	May, 1886.	xv.	lxiii.
XLVI.	St. Louis, Mo.	October, 1886.	xv.	lxx.
XLVII.	Scranton, Pa.*	February, 1887.	xv.	lxxvii.
XLVIII.	Utah and Montana.	July, 1887.	xvi.	xvii.
XLIX.	Duluth, Minn.	July, 1887.	xvi.	xxiv.
L.	Boston, Mass.*	February, 1888.	xvi.	xxviii.
LI.	Birmingham, Ala.	May, 1888.	xvii.	xix.
LII.	Buffalo, N. Y.	October, 1888.	xvii.	xxiv.
LIII.	New York, N. Y.*	February, 1889.	xvii.	xxxi.
LIV.	Colorado.	June, 1889.	xviii.	xvii.
LV.	Ottawa, Canada.	October, 1889.	xviii.	xxiv.
LVI.	Washington, D. C.*	February, 1890.	xviii.	xxx.
LVII.	New York, N. Y.	September, 1890.	xix.	vii.
LVIII.	New York, N. Y.*	February, 1891.	xix.	xxv.
LIX.	Cleveland, O.	June, 1891.	xx.	xvi.
LX.	Glen Summit, Pa.	October, 1891.	xx.	lxi.
LXI.	Baltimore, Md.*	February, 1892.	xxi.	xix.
LXII.	Plattsburgh, N. Y.	June, 1892.	xxi.	xxxiii.
LXIII.	Reading, Pa.	October, 1892.	xxi.	xliv.
LXIV.	Montreal, Canada*	February, 1893.	xxi.	lii.
LXV.	Chicago, Ill.	August, 1893.	xxii.	xiii.
LXVI.	Virginia Beach, Va.*	February, 1894.	xxiv.	xvii.
LXVII.	Bridgeport, Conn.	October, 1894.	xxiv.	xxxv.
LXVIII.	Florida†	March, 1895.	xxv.	xix.
LXIX.	Atlanta, Ga.	October, 1895.	xxv.	xxxiii.
LXX.	Pittsburg, Pa.*	February, 1896.	xxvi.	xvii.
LXXI.	Colorado.	September, 1896.	xxvi.	xxix.
LXXII.	Chicago, Ill.	February, 1897.	xxvii.	xvii.
LXXIII.	Lake Superior.	July, 1897.	xxvii.	xxx.
LXXIV.	Atlantic City, N. J.*	February, 1898.	xxviii.	xvii.
LXXV.	Buffalo, N. Y.	October, 1898.	xxviii.	xxxvi.
LXXVI.	New York City*	February, 1899.	xxix.	xvii.
LXXVII.	California.	September, 1899.	xxix.	xlix.
LXXVIII.	Washington, D. C.*	February, 1900.	xxx.	xix.
LXXIX.	Canada.	August, 1900.	xxx.	xlv.
LXXX.	Richmond, Va.*	February, 1901.	xxxi.	xix.
LXXXI.	Mexico.	November, 1901.	xxxi. and xxxii.	cxviii.
LXXXII.	Philadelphia, Pa.‡	May, 1902.	xxxiii.	xxi. and xxxv.
LXXXIII.	New Haven, Conn.	October, 1902.	xxxiii.	xlvii.
LXXXIV.	Albany, N. Y.*	February, 1903.	xxxiv.	xxiii.
LXXXV.	New York, N. Y.	October, 1903.	xxxiv.	lxi.
LXXXVI.	Atlantic City, N. J.*	February, 1904.	xxxv.	xxiii.
LXXXVII.	Lake Superior.	September, 1904.	xxxv.	xlii.
LXXXVIII.	Washington, D. C.	May, 1905.	xxxvi.	
LXXXIX.	British Columbia.	July, 1905.	xxxvi.	

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* Annual meeting for the election of officers.

† Begun in February at New York City, for the election of officers, and adjourned to Florida.

‡ " " " " " " " " " " " " " to Philadelphia.

PUBLICATIONS.

THE publications of the Institute comprise:

TRANSACTIONS.

The volumes of *Transactions*, which are published annually, contain the list of officers, rules, etc., the Proceedings, and the papers revised for final publication. (In this revision, after the preliminary publication, authors are permitted to use the largest liberty; and the changes and additions made in papers are sometimes important. It should be borne in mind by those who study or quote a paper in the preliminary edition, that they may not have in that form the ultimate and deliberate expression of the author's views. It should be added, however, that in the majority of cases there are no important changes.) These volumes are for sale as follows, in paper covers:

Vols. I. to IV., inclusive, each, ...	$3 00
Vols. V. to VIII., inclusive, each, ...	4 00
Vols. IX. and X. (a small supply only on hand), . .	10 00
Vols. XI. to XXIX., inclusive, each, ...	5 00
Vols. XXX. and XXXI., each, ...	6 00
Vol. XXXII., ...	5 00
Vols. XXXIII. to XXXV., inclusive, each, ...	6 00
Half-morocco binding, $1 extra per volume.	
Complete set of *Transactions*, Vols. I. to XXXV., inclusive, half-morocco binding (freight prepaid), . . .	213 00

INDEXES AND SPECIAL EDITIONS.

Index, Vols. XVI. to XX., inclusive, paper, ...	$1 00
Index, Vols. XXI. to XXV., inclusive, cloth, . . .	1 25
Index, Vols. XXVI. to XXX., inclusive, cloth, . . .	1 50
The last, in half-morocco binding, ...	2 50

"*The Genesis of Ore-Deposits*," comprising the famous treatise of the late Professor Franz Posepny, with the successive discussions thereof by Le Conte, Blake, Winchell, Church, Emmons, Becker, Cazin, Rickard and Raymond (all of which were published in Volumes XXIII. and XXIV. of the *Transactions* of the Institute, and subsequently in the special "Posepny Volume," issued by the Institute); also, later papers by Van Hise, Emmons, Weed, Lindgren, Vogt, Kemp, Blake, Rickard and others, and the discussions of these papers by De Launay, Beck, and many others (some of these were included in Volume XXX. and the remainder appeared in Volume XXXI.); also a complete bibliography of the Institute papers and discussions on this subject from 1871 to the present time.

The original Posepny volume comprised 265 pages, and was sold for $2.50, at which price the edition was long since exhausted. The present volume is an octavo of 825 pages, bound in "book-linen," of the same color as the standard binding of the *Transactions*, . . .	$6 00
Half-morocco bound copies, ...	7 00
"*The Evolution of Mine-Surveying Instruments.*" This is a volume of about 400 pages, issued in the same style as the foregoing, and containing the original paper of Mr. Dunbar D. Scott on that subject (*Transactions*, XXVIII.), first published in 1898, together with later papers, continuing the same subject, and discussions thereof, by Hoskold, Lyman, Davis and many others, .	3 50
Half-morocco binding, ...	4 50
Glossary of Mining and Metallurgical Terms (1881), cloth, .	50
Spanish-American Mining and Metallurgical Glossary, bound in leather, pocket-size, 96 pages, ...	75
Special Mining and Railway Map of Mexico, size 14 by 20, prepared by order of Dept. of Fomento, 1901, . . .	35
List of Members, Rules, etc., paper, ...	50

PAMPHLETS.

1. The Minutes of the Proceedings of each Meeting.

2. Such of the papers presented or read by title at each Meeting as are furnished by the authors and approved by the Council for full publication. (In nearly all cases in which papers, the titles of which appear in the Proceedings, are not subsequently published, they have been withdrawn by the authors.) These papers are published separately in pamphlet form, and are marked "subject to revision." Beyond the edition distributed, without charge, to members and associates not in arrears, a small supply is retained to meet subsequent demand. There are no copies on hand of papers read before 1880. The stock is nearly complete from 1880. These papers are for sale at the office of the Secretary, or are sent to purchasers by mail or express, charges paid, on receipt of the price, as follows:

No. of Pages.	Single Copies.	10 Copies.	20 Copies.
8 or less..........	$0 10	$0 60	$1 00
9 to 12 inclusive....................................	0 10	0 80	1 40
13 to 16 "	0 12	1 00	1 75
17 to 20 "	0 16	1 25	2 25
21 to 24 "	0 20	1 50	2 75
25 to 40 "	0 25	2 00	3 50
41 to 56 "	0 30	2 50	4 50
57 to 72 "	0 35	3 00	5 00
73 to 88 "	0 40	3 25	5 25
89 to 104 "	0 45	3 50	6 00
105 to 120 "	0 50	3 75	6 25

Papers with folders and inserted plates subject to special price.

CONSTITUTION.

[ADOPTED JANUARY 9, 1905.]

ARTICLE I.

NAME AND OBJECT.

SEC. 1. This Institute is incorporated under the Membership Corporation Law of the State of New York; its corporate name is AMERICAN INSTITUTE OF MINING ENGINEERS; and its objects are such as are stated in its Certificate of Incorporation.

ARTICLE II.

MEMBERS.

SEC. 1. The membership of the Institute shall comprise four classes, namely: (1) Members; (2) Honorary Members; (3) Associates; and (4) Honorary Associates. Only Members and Associates residing within the United States of America, Republic of Mexico and Dominion of Canada shall be entitled to vote at the meetings of the Institute.

SEC. 2. All Members, Honorary Members, Associates and Honorary Associates of the American Institute of Mining Engineers as the same existed on the day of the incorporation of this Institute, are Members, Honorary Members, Associates and Honorary Associates, respectively, of this Corporation.

SEC. 3. The following classes of persons shall be eligible for membership in the Institute, namely: as Members and Honorary Members, all professional mining engineers, geologists, metallurgists or chemists, and all persons practically engaged in mining, metallurgy or metallurgical engineering; as Associates and Honorary Associates, all persons desirous of being connected with the Institute who, in the opinion of the Council, are suitable.

SEC. 4. Every candidate for election as a Member or Associate of the Institute must be proposed for election by at least three Members or Associates; must be approved by the Committee on Membership, as prescribed in the By-Laws; and must be elected by the Council. Not less than three-fourths of the votes cast shall be necessary to an election. Every person so elected shall become a Member or Associate, as the case may be, upon payment of his first dues as hereinafter prescribed. Each candidate for Honorary Member or Honorary Associate, must be recommended by at least ten Members or Associates; must be approved by the Council; and must be elected by ballot at a meeting of the Board of Directors by the unanimous vote of all the Directors present; provided, however, that the number of Honorary Members and Honorary Associates shall not at any time exceed twenty.

SEC. 5. If any person elected a Member or Associate does not, within sixty days after notice of his election, accept the same and pay his initiation fee and dues for the current year, his election may be cancelled at the discretion of the Council.

SEC. 6. The Council may at any time change the classification of a person elected as an Associate so as to make him a Member, or vice versa. All Members and Associates shall be equally entitled to the privileges of membership, provided that Honorary Members, Honorary Associates, and Members and Associates whose Post-Office addresses shall be outside of the United States, Mexico and Canada, shall not be entitled to vote.

ARTICLE III.

DUES.

SEC. 1. The dues of Members and Associates shall be Ten Dollars per annum, payable in advance on the first day of each Calendar year. Each newly elected Member or Associate shall pay, when notified of election, an initiation fee of Ten Dollars in addition to the dues for the current year. Honorary Members and Honorary Associates shall not be liable to initiation fee or dues. Any Member or Associate in arrears for one year may, at the discretion of the Council, be deprived of the receipt of publications or stricken from the list of Members, provided that he may be restored to membership by the Council on payment of all arrears or may be again proposed and elected after an interval of three years.

SEC. 2. Any Member or Associate not in arrears may become, by the payment of One Hundred and Fifty Dollars at one time, a Life Member or Associate; and shall not be liable thereafter to annual dues.

ARTICLE IV.

BUSINESS MEETINGS OF THE INSTITUTE.

SEC. 1. The annual meeting of the Institute for the election of Directors and transaction of other business shall take place on the third Tuesday in February in each year. A report of the financial condition of the Institute and an abstract of the accounts shall be furnished by the Directors, and presented at each annual meeting.

SEC. 2. Special business meetings of the Institute may be held at such times and places as the Board of Directors may appoint, upon notice to all Members and Associates entitled to vote, directed to each at his last known Post-Office address, and mailed in the City of New York not less than twenty days before the date fixed for such meeting.

SEC. 3. At all business meetings of the Institute the presence of nine Members and Associates shall constitute a quorum.

SEC. 4. At all business meetings of the Institute Members and Associates may vote either in person or by proxy, but no Member or Associate in arrears since the last annual meeting shall be entitled to vote.

ARTICLE V.

OTHER MEETINGS OF THE INSTITUTE.

SEC. 1. All meetings of the Institute other than business meetings shall be held at such times and places as the Council may appoint. Notice of all such meetings shall be given to all Members and Associates by mail.

ARTICLE VI.

DIRECTORS AND OFFICERS.

SEC. 1. The business and financial affairs of the Institute shall be managed by a Board of Directors, who shall be elected at the annual meeting in the manner prescribed in the Certificate of Incorporation.

SEC. 2. The officers of the corporation shall be a President, Vice-President, Secretary and Treasurer, who shall be elected by the Directors from among their number. All such officers shall be elected at the first meeting of the Board of Directors after each annual meeting of the corporation, and shall hold office for one year or until their successors are elected and qualify.

The duties of all officers shall be such as usually pertain to their offices, respectively, together with such other duties as may from time to time be prescribed for them by the By-Laws. The Treasurer shall give a bond for the faithful performance of his duties in a sum to be fixed by the Board of Directors, but at the expense of the Institute.

SEC. 3. In the event of a vacancy occurring in the Board of Directors by death, resignation or otherwise, the remaining members of the Board may, by a majority vote, elect a successor to fill the vacancy, who shall continue in office until the next annual meeting or until his successor shall have been chosen.

SEC. 4. The Board of Directors may, in its discretion, declare the place of any Director vacant, on his failure for any reason, to attend three successive meetings of the Board. Any Director who shall under this section or in any other manner cease to be a member of the Board shall, at the same time, be held to have vacated any other office to which he shall previously have been elected; and the Board shall elect a new incumbent to the said vacant office.

SEC. 5. The Board of Directors may from time to time appoint from their own number standing and special committees, and may delegate to such committees such duties as they may see fit.

ARTICLE VII.

MEETINGS OF THE BOARD OF DIRECTORS.

SEC. 1. A regular meeting of the Board of Directors for the election of officers and the transaction of other business shall be held on the third Tuesday in February in each year, after the adjournment of the annual meeting of the Institute.

SEC. 2. Special meetings of the Board of Directors, at which any business may be transacted, may be called to meet at any time at the office of the Institute in the City of New York, by notice in writing mailed at least five days before the meeting, by the Secretary to each member of the Board at his last known Post-Office address, signed either by the President or the Vice-President or by three members of the Board.

SEC. 3. At all meetings of the Board of Directors the presence of five members shall constitute a quorum.

ARTICLE VIII.

THE COUNCIL.

SEC. 1. The professional, technical, scientific and social interests of the Institute shall be committed to the supervision of a Council composed of a President of the Council, six Vice-Presidents of the Council, a Secretary of the Council and nine Councilors, who shall be elected from among the Members and Associates of the Institute in the manner hereinafter prescribed. Members of the Council may or may not be members of the Board of Directors.

SEC. 2. The President of the Council shall be elected for one year, and no person shall be eligible for immediate re-election to this office who shall have held the same for two consecutive years.

After the first year Vice-Presidents of the Council shall be elected to serve for two years, and Councilors shall be elected to serve for three years. No Vice-President of the Council or Councilor shall be eligible for immediate re-election to the same office at the expiration of the term for which he was elected. The Secretary of the Council shall be elected annually.

SEC. 3. At the first annual meeting to be held in the year 1905, there shall be elected a President of the Council to serve for one year, a Secretary of the Council to serve for one year, three Vice-Presidents of the Council to serve for one year, three Vice-Presidents of the Council to serve for two years, three Councilors to serve for one year, three Councilors to serve for two years, and three Councilors to serve for three years. At each subsequent annual meeting there shall be elected a President of the Council to serve for one year; a Secretary of the Council to serve for one year; three Vice-Presidents of the Council to serve for two years; and three Councilors to serve for three years. The term of office of all Members of the Council shall continue until the adjournment of the meeting at which their successors are elected.

SEC. 4. Vacancies in the Council may occur by death or resignation; or the Council may, by the vote of a majority of all its members, declare the place of any officer or member of the Council vacant, on his failure for one year, from inability or otherwise, to attend the regular meetings or perform the duties of his office. All vacancies shall be filled by the appointment of the Council, and any person so appointed shall hold office for the remainder of the term for which his predecessor was elected or appointed; *provided* that the said appointment shall not render such person ineligible for election to the Council at the next meeting.

SEC. 5. The presence of five members of the Council shall constitute a quorum; but the Council may appoint an Executive Committee, or any business coming within the authority of the Council may be transacted at a regularly-called meeting thereof, at which less than a quorum may be present, subject to the approval of a majority of the Council subsequently given in writing to the Secretary and recorded by him with the minutes.

SEC. 6. The election of the Council shall take place at the regular annual meeting of the Institute. Nominations for members of the Council may be sent in writing to the Secretary accompanied with the names of the proposers at any time not less than thirty days before the annual meeting; and the Secretary shall, not less than two weeks before said meeting, mail to every Member or Associate entitled to vote a list of all nominations for each office so received, together with the names of the persons ineligible for election to each office; and if the Council or a Committee thereof, appointed for the purpose, shall have recommended any nomination, such recommendation may also be sent to the Members and Associates with the list of all nominations made.

ARTICLE IX.

Meetings of the Council.

Sec. 1. Meetings of the Council shall be held at such times and places as the President of the Council or one of the Vice-Presidents of the Council may appoint.

Sec. 2. A meeting of the Council may be held on the day of the annual meeting of the Institute without previous notice. Written notice of all other meetings of the Council, specifying the time and place of such meeting, signed by the Secretary, shall be mailed to every member of the Council at his last known Post-Office address at least ten days before the date of the meeting.

ARTICLE X.

Papers and Publications.

Sec. 1. The Council shall have power to decide as to the acceptance and publication of any professional papers presented to the Institute, subject to such conditions as the Board of Directors may prescribe.

Sec. 2. The copyright of all professional papers communicated to and accepted by the Institute shall be vested in it, unless otherwise expressly agreed between the Council and the author. The Institute shall not assume responsibility for any statements of fact or opinion advanced in the papers or discussions at its meetings. Neither the Council nor the Institute shall officially approve or disapprove any technical or scientific opinion or any proposed enterprise, outside of the management of the meetings, discussions and publications of the Institute, and the conduct of its business affairs by the Board of Directors.

Sec. 3. Special Committees may from time to time be appointed by the Council to make investigations and prepare reports for presentation to the Institute, but no action shall be taken binding the Institute for or against the conclusions embodied in any such reports.

ARTICLE XI.

Suspensions and Expulsions.

Sec. 1. Any member of the Institute who shall be convicted of a crime involving, in the opinion of the Board of Directors, moral turpitude, shall, upon the passage by the Board of Directors of a resolution declaring the crime for which he has been convicted to be of such character, be thereupon dropped from membership in this Institute.

Sec. 2. Any member of the Institute may be suspended or expelled for misconduct by the Board of Directors, after charges setting forth such misconduct shall have been prepared by the Council and filed in writing with the Board. Upon the receipt of such charges in writing, the Board may, in its discretion, suspend such member pending a hearing and determination thereupon. As soon as may be after the receipt of such charges, the Board shall fix a date for a hearing thereupon and shall give to the accused member notice thereof in writing, mailed to him at his last known Post-Office address not less than thirty days before said date, accompanied by a full copy of the charges and a copy of the second, third and fourth sections of this article.

Sec. 3. Upon the day fixed for the hearing, the accused member may appear before the Board, either in person or by an accredited representative; hear any witnesses who may be called in support of the charges and at his option cross-examine the same; and hear read any documentary evidence offered in support of the charges. The accused may, in his discretion, produce and examine witnesses in his defence, and submit documentary evidence, including a statement from himself in writing. After the conclusion of the hearing, the Board of Directors shall consider and vote to approve or disapprove the charges. If the Board shall, by a vote of two-thirds of its members, declare the charges sustained, it may suspend the member for a stated period or expel him.

SEC. 4. If the accused member shall not appear at the hearing, and shall within three months thereafter file with the Board an affidavit stating that he had not received notice of the charges against him in time to enable him to present his defence, the Board shall fix a date for a re-hearing within three months from the receipt of such affidavit and shall immediately notify the accused member by mail of such date. Upon the re-hearing, the accused shall have the same privilege of presenting his defence as he would have had upon the original hearing; and after the defence is presented, the Board shall take a new vote upon the charges, the result of which shall be conclusive.

SEC. 5. All interests in the property of the Institute of persons resigning, or otherwise ceasing to be Members or Associates, shall vest in the Institute.

ARTICLE XII.

AMENDMENTS.

SEC. 1. This Constitution or any Article or Section thereof may be amended at any annual meeting by a two-thirds vote of all the members present in person or by proxy, *provided* that notice of the proposed amendment shall have been given in writing at a previous meeting, and *provided also* that the amendment or amendments so adopted shall have been printed and mailed to all Members and Associates not later than thirty days before the annual meeting. Any amendment or amendments approved by a majority of the votes cast shall be deemed to have been adopted, and shall become a part of this Constitution. The Secretary shall forthwith print and distribute to Members and Associates an announcement of the result of said vote, and if any amendment or amendments shall have been adopted, a copy of the section or sections so amended.

BY-LAWS.

I. PRESIDING OFFICERS.

At all Business meetings of the Institute the President, or, in his absence, the Vice-President, or, in the absence of both of them, any other member of the Board of Directors to be chosen by the meeting, shall preside.

At all other meetings of the Institute the President of the Council or, in his absence, one of the Vice-Presidents, if present, shall preside.

II. ORDER OF BUSINESS.

At each Business meeting of the Institute the order of business shall be as follows:

1. Reading of minutes of preceding meeting.
2. Report of the President.
3. Report of the Treasurer.
4. Report of the Secretary.
5. Election of Directors.
6. Election of Members of the Council.
7. Reports of Standing Committees.
8. Reports of Special Committees.
9. Special Orders.
10. Miscellaneous business.

This order of business may be changed by a vote of a majority of the Members and Associates present in person or by proxy.

The usual parliamentary rules shall govern all meetings of the Institute except in cases otherwise provided by the Constitution or the By-Laws.

At all sessions of the Institute other than business meetings, the order of proceedings and the time of adjournment, shall rest in the discretion of the presiding officer.

III. SECRETARY.

The Secretary shall keep a record of the proceedings of all meetings of the Institute. He shall be custodian of the Corporate Seal, of the Minute Books, and of all Legal Documents belonging to the Institute. He shall conduct, on behalf of the Institute, all correspondence relating to business matters, except such as pertains directly to the office of the Treasurer.

He shall notify all officers and Directors and Members of the Council, and all Members of Committees of their election and appointment; shall issue notices of all meetings of the Board, and of the annual and other meetings of the Institute; and shall, in calling special meetings of the Directors, specify the object of such meeting.

IV. SECRETARY OF THE COUNCIL.

The Secretary of the Council shall act as the Clerk of that body at all of its meetings and at all meetings of the Institute called for the discussion of professional, technical or scientific matters, or for any other purpose than the transaction of business.

He shall be custodian of all technical or scientific papers submitted to the Institute for its consideration, shall have charge of the editing and printing of all material published by the Institute, and of the distribution thereof. On the first day of May following the year in which each volume of *Transactions* is printed, he shall turn over to the Library Committee all copies of the same not theretofore distributed by him. He shall have charge of all the correspondence of the Institute relating to other than business affairs.

The Secretary of the Council shall receive a salary to be fixed by the Board of Directors. He may appoint an Assistant Editor, who shall likewise receive a salary to be fixed by the Board of Directors.

The Secretary of the Council may or may not be the same person as the Secretary of the Institute.

V. ASSISTANT SECRETARY.

The Secretary may, with the approval of the Board of Directors, appoint an Assistant to whom both he and the Secretary of the Council may delegate such of his or their duties as he or they may see fit. This Assistant Secretary shall receive such salary as shall be fixed by the Board of Directors, which shall cover his services both to the Secretary and to the Secretary of the Council.

VI. TREASURER.

The Treasurer shall collect and, under the direction of the Board of Directors, shall disburse all funds of the Institute. He shall keep regular accounts in books belonging to the Institute, which shall be open to any member of the Board of Directors. He shall report in writing at each annual meeting of the Institute and at every meeting of the Board of Directors at which such report shall be called for, the balance of money on hand, and any existing appropriation which may affect the same.

His accounts shall be audited annually by a Committee of three Members or Associates to be appointed by the President at least thirty days prior to the annual meeting in each year, which Committee shall report thereon at such annual meeting.

The Treasurer may, at his discretion, place funds of the Institute, not at any time exceeding $5,000, in a special account in a Bank or Trust Company, subject to the draft of the Assistant Treasurer, and may delegate to the Assistant Treasurer the duty of paying, out of this account, the current expenses of the Institute.

The Treasurer shall be solely responsible to the Institute for all moneys received, whether the same are entrusted to the Assistant Treasurer or not.

VII. ASSISTANT TREASURER.

The Treasurer may appoint, with the approval of the Board of Directors, an Assistant Treasurer, to whom he may delegate the duty of conducting the correspondence incidental to the office of Treasurer, of receiving and depositing in bank to the credit of the Institute all moneys received, and of paying, out of the special account upon which he may be authorized to draw, the necessary expenses of the Institute. The Treasurer may require of him a bond, running to the Treasurer personally, in an amount not exceeding $5,000, the expense of which shall be borne by the Institute.

The Assistant Treasurer shall receive such compensation as shall be fixed by the Board of Directors.

The offices of the Assistant Secretary and of the Assistant Treasurer may, if so desired by both the Secretary and the Treasurer and approved by the Board of Directors, be united in the same person, who shall then receive the salary of both offices.

The Assistant Treasurer may, with the approval of the Board of Directors, employ such persons as are necessary to constitute a clerical and office force for himself, the Assistant Secretary and the Secretary of the Council, at such salaries as shall be approved by the Board of Directors. He shall, if the offices of Assistant Secretary and Assistant Treasurer be united in the same person, be the immediate superior of all such employees, unless the Secretary of the Council or the Treasurer be present, in which event either of them shall be the superior of all employees, including their respective assistants.

VIII. STANDING COMMITTEES.

The Standing Committees of the Institute shall be three in number, known respectively as the FINANCE COMMITTEE, the LIBRARY COMMITTEE and the COMMITTEE ON MEMBERSHIP.

The FINANCE COMMITTEE and the LIBRARY COMMITTEE shall each consist of three members of the Board of Directors, and shall be appointed by the President at the first meeting of the Board, after the annual meeting in each year.

The COMMITTEE ON MEMBERSHIP shall consist of five Members of the Council, and shall be appointed by the President of the Council, at the first meeting of the Council after the first annual meeting in each year.

IX. FINANCE COMMITTEE.

It shall be the duty of the FINANCE COMMITTEE to inquire into and examine the financial condition of the Institute, and to consider ways and means of increasing its revenues and of limiting its expenses. It shall report from time to time to the Board as often as it may deem expedient, and whenever it shall be directed so to do; and the Treasurer shall at all times furnish it with such statements and information as it may desire.

It shall determine the investment of such surplus moneys as shall from time to time accrue to the Institute. It shall, at least once in each year, examine the securities belonging to the Institute in the custody of the Treasurer, and report thereon to the Board.

It may, at any time, examine the books and vouchers of the Treasurer and Assistant Treasurer.

The Treasurer shall not be a member of the FINANCE COMMITTEE, but shall attend the meetings of the same if requested to do so.

X. LIBRARY COMMITTEE.

The LIBRARY COMMITTEE shall be the custodian of all books in the Institute Library and of additions thereto; also of all back numbers of the *Transactions* of the Institute. It shall, on the first day of May, of each year, receive from the Secretary of the Council, and receipt for same to him, all the volumes of *Transactions* for the preceding year, not then distributed by said Secretary.

It shall cause to be kept, under the direction of the Assistant Secretary, a catalogue of all books in the Library and an account in ledger form of all volumes of *Transactions* in its custody, in which shall be charged to it all volumes delivered to it, and in which shall be credited all volumes taken from its custody for sale or for any other purpose.

The receipts from the sale of any volume of *Transactions* taken from the custody of the LIBRARY COMMITTEE shall be credited to the LIBRARY COMMITTEE on the books of the Treasurer, and devoted to the general purposes of the Institute.

XI. COMMITTEE ON MEMBERSHIP.

All nominations for Members or Associates of the Institute shall be submitted to and passed upon by the COMMITTEE ON MEMBERSHIP, who shall report thereon to the Council. It shall receive and consider all communications respecting candidates, and shall make diligent inquiry as to the character and qualifications of each one. Its proceedings shall be secret and confidential.

No member of the Committee shall propose any candidate.

XII. ELECTION OF MEMBERS.

After the COMMITTEE ON MEMBERSHIP shall have reported to the Council its conclusions as to the acceptability of each candidate, the Council shall vote upon the same.

Two negative votes of members of the Council present shall prevent the election of any candidate. No person shall be proposed for election to the Institute within one year after his name shall have been rejected by the Council.

XIII. UNITED ENGINEERING SOCIETY.

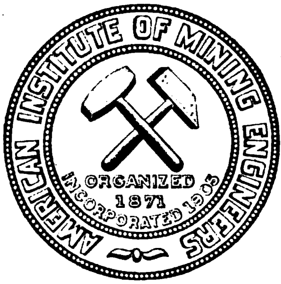
The Board of Directors shall, at its first meeting after the adoption of these By-Laws, designate three Members or Associates of this Institute to be representatives of this Institute upon the Board of Trustees of the UNITED ENGINEERING SOCIETY, making at the same time provision for the expiration of the terms of office of said representatives, as provided in the By-Laws of the said UNITED ENGINEERING SOCIETY.

At the last meeting of the Board of Directors prior to the first day of each January thereafter, the Board shall designate a Member or Associate of this Institute to be a representative of this Institute upon the Board of Trustees of the said UNITED ENGINEERING SOCIETY for a period of three years beginning at the next ensuing annual meeting of said Society.

At any time when a vacancy shall occur in the representation of this Institute in the Board of Trustees of said Society, by reason of the death, resignation or removal of any such representative therein, the Board of Directors of this Institute shall designate a Member or Associate to fill such unexpired term.

XIV. AMENDMENTS.

These By-Laws may at any time be altered or amended by a vote of three-fourths of the Board of Directors, or by the Members, at a business meeting of the Institute, in the same manner provided for amendments of the Constitution in Article XII. thereof.


AMERICAN INSTITUTE OF MINING ENGINEERS
ORGANIZED
1871
INCORPORATED 1905

Sci 1520.112

No. 8. MARCH. 1906.

Bi-Monthly Bulletin

OF THE

American Institute of Mining Engineers.

PUBLISHED BY THE AMERICAN INSTITUTE OF MINING ENGINEERS
At S-W. Cor. Seventh and Cherry Sts.
PHILADELPHIA, PA.
EDITORIAL OFFICE AT 99 JOHN STREET, NEW YORK, N. Y.

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TECHNICAL JOURNALS DESIRING TO REPUBLISH SHOULD APPLY
TO THE SECRETARY, AT 99 JOHN ST., NEW YORK CITY.]

Entered December 6, 1904, at Philadelphia, Pa., as second-class matter under Act of Congress of July 16, 1894.

Aug. 14, 1906.
Bequest of
Erasmus Darwin Leavitt.

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TABLE OF CONTENTS.

SECTION I. INSTITUTE ANNOUNCEMENTS.

PAGE
List of Officers, ... iv
Bi-Monthly Bulletin, ... v
United Engineering Society Building, . . . , ... vi
Proceedings of the Annual Meeting, ... , . . viii
Proceedings of the Board of Directors, ... ix
Proceedings of the Council. xii
Library, ... xvi
Membership, ... xxxiv

SECTION II. TECHNICAL PAPERS.

No. 1. Thomas L. Watson. Lead- and Zinc-Deposits of the Virginia-Tennessee Region, ... 161
No. 2. Thomas L. Watson. The Mining, Preparation and Smelting of Virginia Zinc-Ores, ... 197
No. 3. Joseph Hartshorne. The Kurzwernhart Gas-Saving Process, . 213
No. 4. Alvinus Brown Wood. The Ancient Copper-Mines of Lake Superior, ... 229

PAGE

No. 5. PERSIFOR FRAZER. Discussion of the Paper of MARIUS R. CAMPBELL, "The Classification of Coals," 239

No. 6. S. F. EMMONS. Biographical Notice of GEORGE H. ELDRIDGE, . 247

No. 7. A. BEMENT. Discussion of the Paper of MARIUS R. CAMPBELL, "The Commercial Value of Coal-Mine Sampling," . . . 259

No. 8. THOMAS T. READ. The Secondary Enrichment of Copper-Iron Sulphides, ... 261

No. 9. FREDERICK T. WILLIAMS. The Relative Merits of Large and Small Drilling-Machines in Development-Work, . . . 269

No. 10. CLEMENS C. JONES and R. W. RAYMOND. Discussion of the Paper of JÜPTNER VON JONSTORFF and Others, "Comparison of Methods for the Determination of Carbon and Phosphorus in Steel," 277

No. 11. EDWARD KELLER. Discussion of the Paper of ALLAN GIBB and R. C. PHILP, "The Constitution of Mattes Produced in Copper-Smelting," 281

No. 12. S. S. WYER. Bibliography of Coal-Washing, ... 285

No. 13. JOHN B. HASTINGS and CHARLES P. BERKEY. The Geology and Petrography of the Goldfield Mining-District, Nevada, . . 295

SECTION I.

INSTITUTE ANNOUNCEMENTS.

This section contains announcements of general interest to the members of the Institute but not always of sufficient permanent value to warrant republication in the volumes of the *Transactions*.

OFFICERS.

For the year ending February, 1907.

Council.*

President of the Council.

ROBERT W. HUNT.......................................Chicago, Ill.

(Term expires February, 1907.)

Vice-Presidents of the Council.

WILLIAM P. BLAKE.......................................Tucson, Ariz.
THOMAS F. COLE.......................................Duluth, Minn.
IRVING A. STEARNS.......................................Wilkes-Barre, Pa.

(Term expires February, 1907.)

HENRY M. HOWE.......................................New York, N. Y.
J. B. GRANT.......................................Denver, Colo.
JAMES D. HAGUE.......................................New York, N. Y.

(Term expires February, 1909.)

Councilors.

F. L. GRAMMER.......................................Baltimore, Md.
JOSEPH HARTSHORNE.......................................Pottstown, Pa.
CHARLES H. SNOW.......................................New York, N. Y.

(Term expires February, 1907.)

A. A. BLOW.......................................Washington, D. C.
FRANK LYMAN.......................................New York, N. Y.
T. A. RICKARD.......................................San Francisco, Cal.

(Term expires February, 1908.)

THEODORE DWIGHT.......................................New York, N. Y.
WALTER WOOD.......................................Philadelphia, Pa.
WM. FLEET ROBERTSON.......................................Victoria, B. C., Can.

(Term expires February, 1909.)

Secretary of the Council.

R. W. RAYMOND, No. 99 John Street.......................................New York, N. Y.

(Term expires February, 1907.)

Assistant Secretary and Editor.

JOSEPH STRUTHERS.......................................New York, N. Y.

Corporation.

JAMES GAYLEY, President; JAMES DOUGLAS, Vice-President; R. W. RAYMOND, Secretary; FRANK LYMAN, Treasurer; H. W. B. HOWARD, Assistant Secretary and Assistant Treasurer.

Directors.

JAMES GAYLEY, FRANK KLEPETKO, FRANK LYMAN.

(Term expires February, 1907.)

JAMES DOUGLAS., JAMES F. KEMP, ALBERT R. LEDOUX.

(Term expires February, 1908.)

THEODORE DWIGHT, CHARLES H. SNOW, R. W. RAYMOND.

(Term expires February, 1909.)

Consulting Attorneys, Blair & Rudd, New York, N. Y.

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* Secretary's Note.—The Council is the professional body, having charge of the election of members, the holding of meetings (except business meetings), and the publication of papers, proceedings, etc. The Board of Directors is the body legally responsible for the business management of the Corporation, and is therefore, for convenience, composed of members residing in New York.

BI-MONTHLY BULLETIN.

For the convenience of persons who desire to file, or otherwise use separately, the technical papers in Section II. of the Bulletin, each of these papers has been paged and wired by itself; the whole collection being held together by a single, heavy wire, upon the removal of which it will fall apart into individual pamphlets, substantially like those formerly issued.

A small stock of separate pamphlets, duplicating the technical papers given in Section II. of this Bulletin, is reserved for those who desire extra copies of any single paper.

All communications concerning the contents of this Bulletin should be addressed to Dr. Joseph Struthers, Assistant Secretary and Editor, 99 John St., New York City (P. O. Box 223; Telephone number 5477 John).

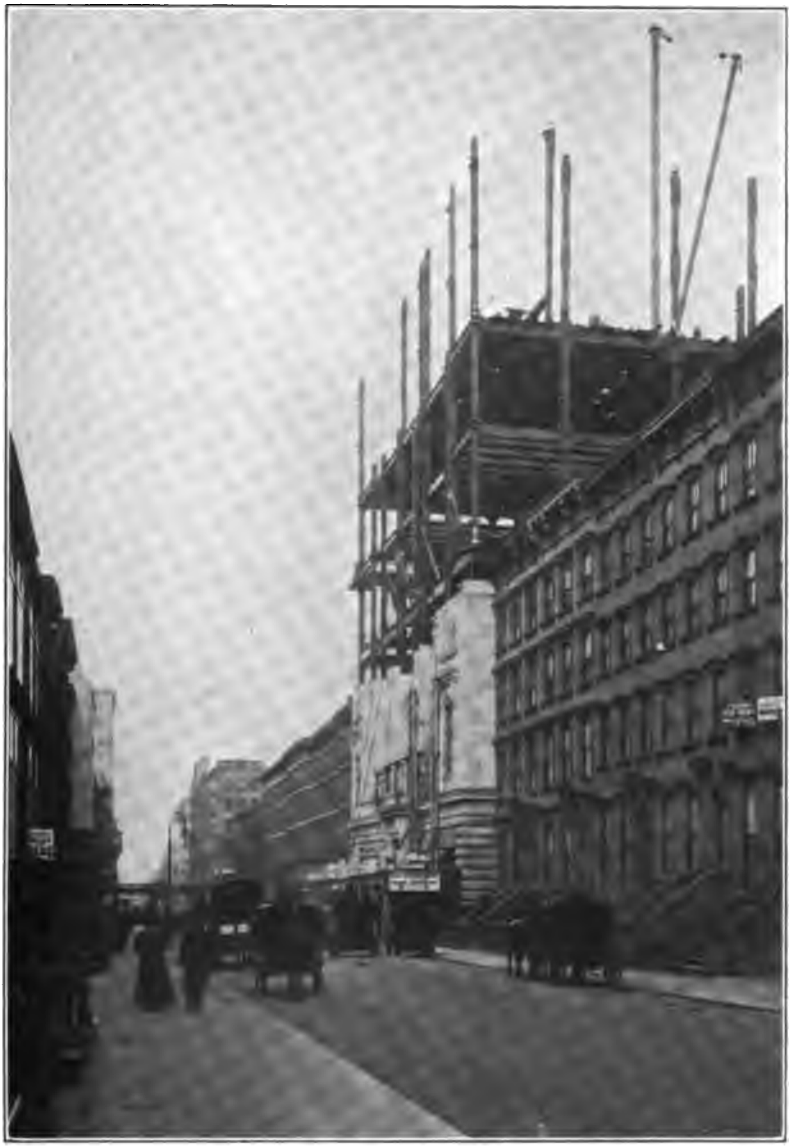
UNITED ENGINEERING SOCIETY BUILDING.

Members of the Institute have already received a special pamphlet descriptive of the United Engineering Society building, and will doubtless be interested in the progress that has been made up to date—February 24th—in erecting this home for the engineering profession.

The old buildings on lots Nos. 25 to 33 W. 39th St., New York, were removed many months ago, but final contracts for the new building were not let until the summer of 1905.

The size of the building is 115 ft. on 39th Street, and 88 ft. in depth; the height from the sidewalk to the top of the parapet is 220 feet. The cubic contents of the building from the bottom of the basement floor to the top of the roof, including the pent houses, is 2,290,000 cubic feet. The number of lights in the building will be between 4,000 and 4,500. The air supply for Auditorium and Lecture Halls will amount to nearly 100,000 cu. ft. per minute, and the exhaust to 90,000 cu. ft. per minute.

In excavating for cellar and foundations, the average depth where good rock was found was 37 ft.—it varied, however, from 27 to 65 ft., due to an old water-course having run through the center of the lot; this condition, and the presence of soft rock, which rapidly disintegrated when exposed to air and water, made the foundation-work very difficult. As two of the column-footings of the building have to sustain a weight of 3,000,000 lb. each, the most substantial foundations are necessary; 13,000 cu. yd. of earth were excavated for the foundation and basement; and 1,600 cu. yd. of concrete were necessary to build up the footings. In the completed building there will be about 3,500,000 bricks. Owing to the number of auditoriums, and their location, and the placing of the library on the top floor, where allowance will have to be made for the enormous weight of 300,000 books, the structural steel work has been unusually complicated in this building. For instance, over the auditorium there are two 60-ton plate-girders, made up



View of United Engineering Society Building, Nos. 25 to 33 West 39th St., New York City, taken March 1, 1906.

of three 20-ton girders in parallel; and at each end of the auditorium one 40-ton plate-girder. Again, above the Assembly Floor, there is a lattice-girder which weighs 60 tons. The two columns which run up to the bottom of this lattice-girder, for a distance of 40 ft., weigh 1,000 lb. per foot. The floors throughout the building will be of marble, terrazzo or cement, laid over terra cotta arches, with the sole exception of the lecture halls, where fire-proof maple will be used. The woodwork throughout the building will be fire-proofed and the window-frames kalamined.

At the present time the structural steel-work is two floors above the level of the adjoining 4-story and basement brown stone houses, which is equivalent, in our building, to the span over the lecture floor; and the brick-work has reached the level of the adjoining buildings on the sides and rear. A photographic view of the building, taken March 1, 1906, is given on the opposite page. The limestone front is being put in place. Unfortunately, owing to the strike of the housesmiths (structural-steel men), the steel work was delayed for about five weeks.

Many members of the Institute, who are also members of the Engineers' Club, will be glad to know that work is also progressing on their building, which adjoins the rear of our own, and that it is also expected that this will be open for occupancy by the same date, if not earlier.

THEODORE DWIGHT.

PROCEEDINGS OF THE ANNUAL MEETING.

At the Annual Business Meeting of the Institute, held February 20, 1906, the following persons were elected:—

Directors.

(To serve three years.)

Theodore Dwight, Rossiter W. Raymond and Charles H. Snow, all of New York, N. Y.

Council.

President of the Council, Robert W. Hunt, Chicago, Ill. *Vice-Presidents* (for two years), Henry M. Howe, New York, N. Y.; J. B. Grant, Denver, Colo.; and James D. Hague, New York, N. Y. *Councilors* (for three years), Walter Wood, Philadelphia, Pa.; William F. Robertson, Victoria, B. C.; and Theodore Dwight, New York, N. Y. *Secretary of the Council* (for one year), Rossiter W. Raymond, New York, N. Y.

[Secretary's Note.—The complete list of all officers of the Institute will be found on p. iv. of this number of the *Bulletin.* The following explanation may recall to old members, and convey to new ones, the relations of the two governing bodies, as determined by the Certificate of Incorporation of the Institute, and the Constitution and By-Laws adopted in accordance therewith.

The body legally responsible for the business management is the Board of nine Directors (three elected annually to serve three years), which elects its own officers. This body, for reasons of practical convenience, is composed of well-known members, residing in New York City, and able to attend, without serious inconvenience or expense, the necessary meetings of the Board. The officers of this Board are legally the officers of the Institute. But, apart from business management, the Board exercises no control over the election of members, or the professional and technical work of the Institute, except that its vote is required to elect honorary members, upon the recommendation of the Council.

The Council is a body, constituted in all respects (except that it has no Treasurer) like the Council existing before the incorporation of the Institute, in January, 1905, and charged with all duties and powers, except those which the Board of Directors must legally perform. It elects members, appoints the times and places of professional meetings, and controls the publication and distribution of papers and volumes, etc. Its members (President, Vice-Presidents and Councilors) are elected by the members of the Institute, voting in person or by proxy, and after publication of the nominations received; and it is intended to represent, as far as practicable, both the professional and the geographical distribution of the membership. Consequently, whatever professional honor attaches to official position belongs to membership in the Council, rather than in the legal Board of Directors. This remark implies no disparagement of the members of the latter body, every one of whom has served, or is now serving, as a member of the Council. But it is only fair to explain that their election and continued re-election as Directors is simply a matter of legal convenience.]

PROCEEDINGS OF THE BOARD OF DIRECTORS.

The following acts of the Directors are reported for the information of members:—

At a meeting held November 3, 1905, Messrs. Henri Le Chatelier, of Paris, France, and Andrew Carnegie, of New York, N. Y., having been nominated by a large number of members, and recommended by unanimous vote of the Council, were unanimously elected Honorary Members, in recognition of their distinguished services to the arts and professions represented by the Institute.

At a meeting held February 7, 1906, Dr. James Douglas, of New York, N. Y., having been nominated by a large number of leading members, and recommended by unanimous vote of the Council, was unanimously elected an Honorary Member, in recognition of his distinguished services to the practice and the literature of mining and metallurgy, his zealous and loyal devotion to this Institute, his fraternal generosity towards professional colleagues, and his effective advocacy, by public utterance and private example, of the free communication of technical knowledge and experience.

At the same meeting, By-Law IV., which now authorizes the Secretary to appoint an "Assistant Editor," was amended by substituting the words, "Assistant with the title of Editor."

At the same meeting, the resignation of Mr. Theodore Dwight, as Assistant Secretary and Assistant Treasurer of the Institute, was presented and accepted, and the Secretary was instructed to express to Mr. Dwight the thanks of the Board for his loyal and efficient services, and its regret that he could not continue in that position.

[SECRETARY'S NOTE.—Mr. Dwight's resignation, dictated solely by the demands of private business, covers only his immediate management of this office. He is still a Director and Councilor, and a representative of the Institute in matters connected with the new Carnegie Building, etc.—R. W. R.]

At the same meeting, the Secretary and the Treasurer reported respectively their appointment of Mr. Henry W. B. Howard as Assistant Secretary and Assistant Treasurer, to fill the vacancies created by the resignation of those offices by Mr. Dwight; and the said appointments were confirmed.

At a meeting of the Board, held February 20, 1906, after the adjournment of the Annual Meeting of the Institute, the following officers were elected for the ensuing year:—*President*, James Gayley; *Vice-President*, James Douglas; *Secretary*, R. W. Raymond; *Treasurer*, Frank Lyman.

FINANCIAL STATEMENT.

The following statement of receipts and expenditures from January 9 to December 31, 1905, is published by authority of the Board of Directors.

RECEIPTS.

Balance from statement of January, 1905,		$9,401.58
Annual dues,	$29,109.48	
Life memberships,	2,592.49	
Initiation fees,	3,200.28	
Binding of *Transactions*,	2,823.65	
Sale of publications,	2,960.60	
Electrotypes,	72.50	
Miscellaneous receipts,	633.90	
Interest on bonds and deposits,	1,192.88	
		42,585.78
		$51,987.36

DISBURSEMENTS.

Printing Vol. XXXV. of the *Transactions*,	$4,129.64
" *Bi-Monthly Bulletin* and pamphlet edition of papers,	6,468.35
" circulars and ballots,	349.80
" special editions,	32.25
" new edition "Genesis of Ore-Deposits,"	60.00
Binding Vol. XXXV. of the *Transactions*,	2,863.36
" miscellaneous volumes,	355.18
" of exchanges,	262.90
Engraving and electrotyping,	731.31
Secretary's department, including editorial work,	9,510.00
Postage, including post-office box rental,	1,755.68
Stationery,	675.82
Rent,	2,750.00
Express and freight charges.	2,557.69
Treasurer's department, including collection of dues, shipping, etc.,	7,291.34
Telephone,	280.60
Telegrams, cables and carfare,	128.11
Storage of *Transactions*,	180.38
Office supplies and repairs,	172.93
Librarian and assistant,	1,360.00
Refunding payments,	39.99

Insurance premiums, fire and surety,	277.74	
Collection charges,	35,19	
Extra clerical help,	60.00	
Special stenographers and expenses of meetings,	1,096.64	
Auditing,	125.00	
Office cleaning and sundry expenses,	103.89	
		$43,653.79
Incorporation expenses,		1,071.75
Office equipments,		143.65
Library additions.		299.21
Balance,		6,818.96
		$51,987.36

NOTE.—It should be borne in mind that by reason of the fact that the incorporation of the Institute was completed January 9, 1905, and the final financial statement of the former Council was brought to that date, the present statement begins with January 9, instead of January 1, as future annual statements will do. It omits, therefore, the receipts and expenditures for the first nine days of 1905, during which period $6,841.62 was received (almost all for dues of 1905), and only $100 was expended (for weekly salaries). In other words, $6,741.62, excess of receipts over expenditures, belonging strictly to 1905, is included in the "Balance from Last Account," at the head of this statement. The receipts for the whole year were, therefore, $49,427.40, and the expenditures $45,278.40, showing a surplus of $4,149.00.

This statement does not include a payment made on account of the Institute to "United Engineering Society," in connection with the Carnegie Engineering Building—the amount of which was supplied from a special fund, raised by voluntary subscription. The full account of this fund will be separately published, at the proper time, by the Committee having it in charge.

PROCEEDINGS OF THE COUNCIL.

The following report, prepared by the Secretary, is published by authority of the Council:—

Meetings.

Two meetings for the reading of papers, etc., have been held during the year, namely, the Eighty-Eighth,* held May 2d to 5th, at Washington, D. C., and the Eighty-Ninth, held July 1st to 5th, at Victoria, B. C.

The proceedings of these meetings, including descriptions of the entertainments and excursions connected therewith, have already been published and distributed to the members of the Institute; the Washington meeting in *Bi-Monthly Bulletin*, No. 4, July, 1905, pp. 913 to 937, and the British Columbia meeting in *Bi-Monthly Bulletin*, No. 6, November, 1905, pp. 1342 to 1413. It is, therefore, not necessary to include them in this report. The meetings were highly successful, both professionally, on account of the large number of valuable papers presented, and socially, through the various delightful excursions and entertainments provided for the visiting members and guests.

At the Washington meeting, 53 papers and discussions were presented, and the number of names registered at the local headquarters amounted to 145; this number, however, does not fully represent all who were present at the sessions and excursions. At the British Columbia meeting, 23 papers and discussions were presented, and 98 members and guests constituted the special excursion to Dawson and return. In addition to these, many local members and guests attended the sessions at Victoria, and accompanied the party on various excursions at Nelson, Rossland, Grand Forks, Victoria, White Horse, Dawson and Vancouver.

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* Prior to the incorporation of the Institute, the Annual Meeting was simply one of the regular meetings, and was mainly occupied, like the rest, with the reading and discussion of papers. At present, the Annual Meeting is devoted to business only. Consequently, it will not be hereafter numbered serially in the list of meetings. (See *Bi-Monthly Bulletin*, No. 4, July, 1905, p. 913.)

Publications.

Transactions.—Volume XXXV. of the *Transactions*, an octavo of 1138 pages, comprising 90 papers and discussions presented during the year 1904, was issued and distributed early in July, a gain in time of 4 months over the appearance of Volume XXXIV., and of 9 months over that of Volume XXXIII.

The material (excepting the index) for Volume XXXVI., which will contain about 1025 pages, is now in the hands of the printer, and, although a strike of compositors has delayed the progress on the work, the volume should be printed and distributed to the members in June, 1906.

Index.—The preparation of former collective indexes of the *Transactions* for Volumes I. to XV., XVI. to XX., XXI. to XXV., and XXVI. to XXX., respectively, has proved so important in making our *Transactions* a convenient cyclopædia of practice and progress for all students of modern mining and metallurgy, that a single index, containing all the references to material in Volumes I. to XXXV., inclusive, is now being assembled. It is hoped that this collective index, probably comprising 800 or 900 pages, will be ready for distribution in September, 1906.

Bi-Monthly Bulletin.—The technical papers which, prior to 1905, had been distributed as separate pamphlets, were issued during this year in the form of a bi-monthly bulletin, under the management of Dr. Joseph Struthers, Assistant Secretary and Editor. In order that the individual technical papers may be filed or otherwise used separately, each one has been paged and wired by itself, the whole collection being held together by a single wire staple, upon the removal of which it will fall apart into individual pamphlets, substantially like those formerly issued. In addition to the technical papers, the *Bulletin* contains announcements of general interest to the members of the Institute, such as lists of accessions to our library, election of new members, etc.

This change, which was made in order to secure the advantage in postal rates given by the U. S. Post Office to periodicals constituting the second class of mail matter, has resulted in a saving of at least $1,200 in the cost of postage for the year.

The six numbers of the *Bulletin* issued during 1905 comprised 1,413 pages of technical papers and discussions, and 115 pages of special announcements, a total of 1,528 pages; thus furnishing to the members more than 500 pages of reading matter, in addition to that which will be included in Volume XXXVI. of the *Transactions*.

The successful publication of the *Bulletin*, and the early appearance of Volume XXXV., have been the results of the efficient work of Dr. Struthers.

Membership.

Changes in membership have taken place during the year as follows:—1 honorary member (not previously on the regular list of members), 322 members, and 19 associates have been elected; 1 member has been elected an honorary member, and 5 associates have become members; the deaths of 1 honorary member, 34 members, and 5 associates have been reported; 46 members and 5 associates have resigned, and 48 members and 1 associate have been dropped from the roll by reason of nonpayment of dues, loss of correct address, etc.* These changes are shown in the accompanying table.

The total membership on January 1, 1906, was 3,884, as compared with 3,680 on January 1, 1905—a net gain for the year of 204 members.

Membership of the American Institute of Mining Engineers, January 1, 1906.

	Honorary Members.	Members.	Associate Members.	Totals.
Membership Dec. 31, 1904	7	3,483	190	3,680
Gains: By Election	1	322	19	342
Change of Status	1	4		5
Reinstatement		1		1
Re-election		1		1
Losses: By Resignation		46	5	51
Dropping		48	1	49
Change of Status		1	4	5
Death	1	34	5	40
Total gains	2	328	19	349
Total losses	1	129	15	145
Membership Dec. 31, 1905	8	3,682	194	3,884

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* Many of these, no doubt, will be reinstated, as has been the case in former years.

The list of deaths reported during the year comprises the following names:*—

Honorary Member.—Dr. Bruno Kerl.

Members and Associates.—Charles Christy Adams (1903), John Wesley Anderson (1898), William Burton Barber (1901), Thomas A. Bennett (1900), Luke W. Bryan (1901), Edwin S. Daugherty (1905), William Scott de Camp (1875), George H. Eldridge (1889), B. W. Frazier (1871), John Broome Guinn, Jr. (1897), Dana C. Irish (1900), Harry Hugh Lee (1899), William Alfred Lindsay (1902), Robert C. Luther (1884), James MacNaughton (1893), Gordon McLean (1899), Herbert Holmes McNamara (1902), August R. Meyer (1886), William Orr (1897), William J. Parker, Jr. (1898), Joseph Phillips, Jr. (1895), Charles O. Ripley (1902), Emmerich J. Schmitz (1883), Ludwig Philip Seeger (1900), Jacob Johnston Sperry (1900), Gustavus H. Stoiber (1902), William L. Study (1905), Robert Macnair Wilson Swan (1900), Richard Henry Terhune (1886), Joseph Thiry (1892), John N. Tisdale (1903), Alfred Isham Totten (1897), Walter H. Virgoe (1902), Charles H. Wellman (1890).

Biographical Notices of Thomas M. Drown,† Bruno Kerl,‡ Benjamin West Frazier,§ and Sir Lowthian Bell‖ have been prepared separately and published in the *Bi-Monthly Bulletin* prior to incorporation in Volume XXXVI. of the *Transactions*, and a Biographical Notice of Edward Cooper is now in press. Concerning the remaining names in the above list, such data as the Secretary has been able to obtain will be published in *Bi-Monthly Bulletin*, No. 9, May, 1906, under the title, "Biographical Notices of 1905." Any appropriate biographical data concerning these names, or others not in the above list which may be received hereafter, will be included in the Biographical Notices of 1906, to be published next year.

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* The figures in parenthesis indicate the year in which the persons named were elected by the Institute.

† *Bi-Monthly Bulletin*, No. 4, July, 1905, pp. 859 to 876.

‡ *Bi-Monthly Bulletin*, No. 4, July, 1905, pp. 743 to 746.

§ *Bi-Monthly Bulletin*, No. 5, September, 1905, pp. 1097 to 1106.

‖ *Bi-Monthly Bulletin*, No. 5, September, 1905, pp. 1079 to 1090.

LIBRARY.

REPORT OF THE LIBRARY COMMITTEE.

To the Board of Directors:

Gentlemen:—The Library Committee begs to submit the following report for the year ending December 31, 1905.

The Committee has deemed it advisable not to propose during the year any change of method or practice in the administration of the library, which has been consequently continued, under the general superintendence of the Secretary, and with the assent of the Committee, as it existed at the time of the incorporation of the Institute. That system, in the opinion of the Committee, was well adapted to the circumstances, though certain questions of growing importance would undoubtedly call for future consideration. Among these, the most important, perhaps, were: the extent and conditions of the "exchange list" and the "free list," of both the *Bi-Monthly Bulletin* and the volumes of *Transactions;* and the purchase of books, and the subscription to periodicals, not obtainable by exchange, yet deemed essential to the completeness of the library.

As to both of these, immediate action was deemed unadvisable, for the following reasons:—

1. In view of the removal of the Institute library, in the near future, to the Carnegie Engineering Building, it is not desirable to alter the present list of exchanges, since it is to be anticipated that, after that event, the exchange-lists of the Societies of Mechanical and Electrical Engineers will be so modified, together with that of the Institute, as to avoid unnecessary duplication.

2. In view of the same event, and of the consequent present uncertainty as to the amount of money which the Institute will be able thereafter to expend upon the increasing and perfecting of its library, it is not desirable, at present, to enter upon new plans for such expenditure.

In accordance with these views of the Committee, the "free-list" of the Institute (i.e., the list of institutions, societies, libraries, etc., to which publications are sent without adequate return in kind) has not been increased during the past year; and the exchange-list has probably experienced little or no net increase, the addresses added for good reasons being counterbalanced by those struck out, for reasons equally valid. And the amount of $299.21, expended between January 9 and December 31, 1905, according to the Treasurer's report, on "library additions," comprises such expenditures as were deemed by the Secretary immediately desirable and important.

3. In addition to the foregoing considerations, the Committee felt that, before the formation of plans for the future, it was well-nigh indispensable to have a complete statement of the past history and present condition of the Institute library.

Before July, 1901, the library consisted only of such files as had been accumulated since the burning of Pardee Hall, at Easton, Pa., in 1879, in which conflagration the precious files were destroyed; and it was regarded simply as a convenient adjunct to the work of the Secretary in editing the *Transactions.* Between 1901 and 1905 it was largely increased from other sources, yet without change in its practical status. No official reports concerning it were presented to the Council. Consequently, this Committee found no previous official statements which could be used as a basis for its own further inquiries and suggestions.

This deficiency has been repaired by the admirably clear and thorough report of Miss L. E. Howard, Librarian of the Institute, which the Committee takes pleasure in transmitting to the Board with this report, and in connection with which the Committee desires to say that, through the skill, devotion, tact and tireless industry of Miss Howard, exercised in the attainment of personal knowledge of the contents of the books and periodicals in the library, the acquisition of material requisite for the completion of defective series of valuable periodicals, the preparation of a thorough and well-arranged card-catalogue, and the intelligent personal guidance given to consulting visitors, the library of the Institute has become already known as a remarkably complete and useful repertory of modern science and practice in the departments which it represents, and is visited daily by many students in those departments.

The Committee heartily recommends to the Board an official recognition of the devotion, industry and skill of the Librarian.

JAMES F. KEMP,
CHAS. H. SNOW,
R. W. RAYMOND,
Library Committee.

REPORT OF THE LIBRARIAN.

The following report, transmitted by the Library Committee, was accepted by the Board of Directors, and, by a resolution, unanimously adopted, the thanks of the Board were expressed to the Librarian for her devoted and skillful discharge of the complicated and onerous duties of her position.

REPORT OF THE LIBRARY FROM JULY, 1901, TO DECEMBER 31, 1905.

To the Library Committee:

Prior to July, 1901, the library of the Institute consisted of the bound volumes of periodicals received in exchange for the *Transactions*, together with a few important works of reference, amounting in all to some 3,273 titles and about 3,600 volumes, 1,673 pamphlets and 500 maps. The exact number cannot be fixed accurately, for the reason that many scientific books, belonging to the Secretary personally, were included in the collection as necessary to his editorial work, while no separate catalogue was made of those which were actually the property of the Institute. Dr. Raymond's subsequent gift of these books and also of the rest of his professional library removed this distinction of ownership, and increased the number to 4,099 titles and 4,600 volumes. After the death of Mr. Alfred Raymond, the son and accomplished assistant of the Secretary, Mr. John Hays Hammond, having purchased the libraries of the late R. P. Rothwell and of the late Clarence King, presented them to the Institute as a memorial of his friend Alfred Raymond. The books comprised in these three libraries are suitably marked by book-plates as belonging to the Alfred Raymond Memorial, and aggregate 6,980 titles, 5,811 volumes, 3,860 pamphlets and 325 maps.

Among the very valuable geological works in Mr. King's library were many volumes of periodicals and publications of societies, which, added to those already on our shelves, supplemented, and in a number of cases completed, the sets. The following may be mentioned:—

**Annales des Mines*, 121 volumes.

**American Journal of Science*, 192 volumes.

Archiv für Mineralogie, Geognosie, Bergbau und Hüttenkunde, 26 volumes.

British Association for the Advancement of Science, 44 volumes.

**Geological Society of London*, 52 volumes.

**Journal des Mines*, 40 volumes.

**Nature*, 55 volumes.

Neues Jahrbuch für Mineralogie, Geologie, etc., 36 volumes.

Petermann's Geographische Mittheilungen, 47 volumes.

Philosophical Magazine, 162 volumes.

Royal Society of London. Philosophical Transactions, abridged, 12 volumes; unabridged, 81 volumes.

——— *Catalogue of Scientific Papers*, 5 volumes.

Bulletin de la Société Géologique de France, 60 volumes.

Mr. Rothwell's library, with the exception of a complete set of the *Engineering and Mining Journal*, contained general works on engineering subjects in French and English.

In 1902 Mr. Anton Eilers presented 113 volumes of *Dingler's Polytechnisches Journal* (including two volumes of indices).

The private engineering library of Mr. William Van Slooten, a deceased member of the Institute, was donated by his wife in 1903, with the request that the collection be inscribed with the donor's name.

Through the generosity of Mr. J. H. Harden, a member, the library was able to complete partially its set of the *Transactions of the North of England Institution of Mining and Mechanical Engineers*. He supplemented this gift with the early volumes of the *Transactions of the Chesterfield and Derbyshire Institute of Mining, Civil and Mechanical Engineers*, and with several volumes of books on mineralogy, mining and geology.

The *Engineering and Mining Journal* contributed 250 volumes (bound and unbound) and 880 pamphlets in 1904. By this donation the library acquired a large number of State geological publications which had been out of print for years.

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* Complete.

Dr. James Douglas, in 1905, presented the *Canadian Naturalist and Geologist* (11 vols.); *Proceedings of the American Association of Arts and Science* (3 vols); and the *Proceedings of the American Association for the Advancement of Arts and Science* (21 vols.).

Mr. Theodore Dwight donated a miscellaneous collection on electrical subjects, comprising 192 pamphlets; 118 photographs; 257 blue prints; 24 maps and 3 specifications; total, 594.

Following is a list of donors to December 31, 1905:—

Richard Åkerman.
J. G. Aguilera.
American Mining Congress.
B. Anderton.
L. E. Aubury.
Mr. and Mrs. S. P. Avery.
D. M. Barringer.
Richard Beck.
J. M. Bel.
R. J. Bestor.
Mr. Bidwell.
Black Hill's Mining Men's Association.
A. A. Blair.
Prof. William P. Blake.
Prof. William Borchers.
Boston Testing Laboratories.
Bowdoin College Library.
Prof. John C. Branner.
British Museum.
Bennett H. Brough.
Canadian Patent Office.
Carnegie Library of Pittsburgh.
Carnegie Steel Company.
R. E. Chism.
Prof. Samuel B. Christy.
A. L. Colby.
Commissão do Servico Geologico de Portugal.
F. G. Corning.
E. Daggett.
C. D. Demond.
Prof. F. G. Doeltz.
Vve C. H. Dunod.
G. Eiffel.
Engineering Standards Committee.
A. Faber du Faur.
B. F. Fackenthal, Jr.
B. Forrester.
Prof. Chas. H. Fulton.
W. J. Furnival.
Geological Commission of the Cape of Good Hope.
Geological Survey of Maryland.
German Imperial Patent Office.
H. P. Gillette.
Glückauf.
H. A. Gordon.
Great Britain Patent Office.
U. S. Grant.
Léon Guillet.
Eugene Haanel.
R. A. Hadfield.
Hans Höfer.
L. E. Howard.
Prof. Henry M. Howe.
Imperial German Consulate, New York City.
Department of Geology and Natural Resources of Indiana.
Iron Age.
Iron and Steel Institute.
Jeffrey Mfg. Company.
John Crerar Library.
F. A. Jones.
Jones and Laughlin Company.
Prof. James F. Kemp.
Königliche Technische Hochschule zu Aachen.
Königlich Preussischen Geologischen Landesanstalt und Bergakademie zu Berlin.
R. G. Leckie.
Dr. Albert R. Ledoux.
David Levat.

Henri Le Chatelier.
Library of Congress.
Library of Princeton College.
J. B. Lippincott Company.
A. Liveridge.
R. W. Lodge.
Prof. N. W. Lord.
Frank Lyman.
W. A. McLeod.
The Macmillan Company.
A. Martens.
Massachusetts State Library.
J. H. Mayo.
Mechanics' Institute of San Francisco.
G. P. Merrill.
Minnesota Geological and Natural History Survey.
Richard G. Moldenke.
R. S. Morison.
Prof. A. J. Moses.
A. Neuberger.
North of England Institute of Mining and Mechanical Engineers.
F. Osmond.
James Park.
E. W. Parker.
Peabody Institute, Baltimore.
Pencoyd Iron Works.
Pennsylvania R. R. Company.
Prof. G. H. Perkins.
Prof. Robert H. Richards.
L. D. Ricketts.
Prof. Heinrich Ries.
J. G. Roby.
E. F. Roeber.
W. L. Saunders.
Sauveur and Whiting.
Secretaria de Fomento de Mexico.
W. J. Sharwood.
F. H. Smith.
Smithsonian Institution.
Prof. H. L. Smyth.
Prof. Charles H. Snow.
Joseph Squire.
H. H. Stoek.
Dr. Joseph Struthers.
W. C Stubbs.
James Swank.
A. Thacher.
Thomas Iron Company.
United States Census Department.
United States Patent Office.
United States War Department.
University of Oregon.
University of Wyoming.
Prof. C. R. Van Hise.
D. Van Nostrand Company.
Verein Deutscher Ingenieure.
Verein für die Bergbaulichen Interessen im Oberbergamts Bezirk Dortmund.
Otto Vogel.
H. L. Vogt.
Dr. Leonard Waldo.
T. L. Watson.
John Wiley and Sons.
Gardner F. Williams.
Wisconsin Geological and Natural History Survey.
Yaqui Copper Company.

The library contained, up to the end of December 31, 1905, 15,350 titles; 14,820 volumes; 1,084 maps; 6,413 pamphlets; 277 blue prints; 137 plans and diagrams; 221 photographs; 651 portraits; and 29 charts; making a total collection of 23,632.

LIBRARY STATISTICS.

	Titles.	Vols.	Pamphlets.	Maps.	Photographs.	Miscellaneous.
Old Library, . .	3,273	3,600	1,673	500		
Alfred Raymond Memorial, . .	6,980	5,811	3,860	325		
Van Slooten Library, ...	625	650				
Other Donations,	2,224	2,562		70	221 pho. 651 por. 277 blue prints.	137 plans. 29 charts.
Vols. bound, . .	750	1,188				
Purchases, . . .	682	759		4		
Gift from E. and M. Journal, . .	816	250	880	185		
	15,350	14,820	6,413	1,084	1,149	166

Summary.

Volumes,	14,820
Pamphlets,	6,413
Maps,	1,084
Photographs,	221
Portraits,	651
Blue prints,	277
Plans,	137
Charts,	29
	23,632
Duplicates,	963
	24,595

Three boxes of duplicates are in storage in Brooklyn, while the remainder have been wrapped and shelved in the library. Sale duplicate-slips have been made for the entire collection.

A card-catalogue (author, subject and title) is in course of preparation and is almost completed. The Library of Congress cataloguing-cards (representing the subjects of Metallurgy, Mining, Geology and Mineralogy) have been used for the author-entry of all books in the library. The remaining cards are filed with the technical bibliographical list of publications not in the library.

All of the bound volumes have been classified by the Dewey Decimal Classification System, excepting those in Room 47. A numerical shelf-arrangement is followed in this room, running from 100 to 1,000.

The pamphlets are closely classified by the above system and arranged on the shelves in pamphlet-boxes, labeled with class-number and contents. The most important will be bound singly or in groups, according to subjects, and incorporated into the library.

Beside the works on geology, metallurgy, mining and mineralogy, there are several hundred volumes embracing mathematics, physics, chemistry, economics, geography and travel, which were added by donation.

There are 367 periodicals and publications of societies, which are received in exchange for the *Transactions* and the *Bi-Monthly Bulletin*, by subscription, and by gift, as follows:—

By exchange for *Transactions*,	115
By exchange for *Bi-Monthly Bulletin*,	134
By exchange *Bi-Monthly Bulletin* and *Transactions*,	69
By gift,	27
By subscription,	22
	367

Two years ago a color-scheme of classification was adopted for binding the periodicals, and has given satisfaction. Each periodical is bound in a shade of cloth, representing its subject, while its nationality (that is, French, German, English, etc.) is indicated by the color of leather used for the binder's title.

The following losses of books are reported:—

Brush, Manual of Determinative Mineralogy, Edition 14, 1896; Edition 16, 1904.
Dana, System of Mineralogy, Edition 6, 1896.
Fresenius, Manual of Qualitative Chemical Analysis, 1902.
Guanajuato Consolidated Mining and Milling Co. Gold and Silver Mines and Mills . . . . in and near Guanajuato, N. Y., n. d.
Moreing and Neil, New General and Mining Code, cop. 2.
Ostwald, Inorganic Chemistry, translated by Findlay, 1902.
Phillips, J. A., Metallurgy and Mining of Gold and Silver, 1867.
Raymond, Glossary of Mining and Metallurgical Terms, cop. 1.
——— Historical Sketch of Mining Law, cop. 1.

The percentage of books lost is relatively small when compared with the figures of other libraries. The open-shelf system has been in vogue, but for the present it has been decided to withdraw the privilege of freely consulting the stacks in room 49.

No statistics of the attendance in the library were kept prior to June, 1902. The following figures cover the years 1902 (June–December) to 1905 inclusive; 1902, 150; 1903, 275; 1904, 793; and 1905, 712. The increase for 1904 was probably due to the Annual Meeting of the Iron and Steel Institute in New York City.

The collection of portraits of members of the Institute which were used for the collective photograph, have been filed alphabetically in vertical filing cabinets.

The trade-catalogues, of which the library possesses about seven hundred copies, have been classified by subject and arranged in pamphlet boxes. An alphabetical index of the manufacturing firms represented has been written, to supplement the subject-classification.

It is asked that an appropriation be made for the purchase of back volumes of the following periodicals:—

Annales des Mines de Belgique.
Berg-und Hüttenmannische Zeitung.
Berichte der Deutsche Chemische Gesellschaft.
Glückauf.
Jern Kontorets Annaler.
Journal and Proceedings Chemical Society of London.
Journal of the Society of Chemical Industry.
Neues Jahrbuch für Mineralogie Géognosie, Geologie und Petrefaktenkunde.
Oesterreichische Zeitschrift für Berg- und Hüttenwesen.
Proceedings of the Institution of Civil Engineers.
Stahl und Eisen.
Transactions of the North of England Institute of Mining and Mechanical Engineers.
Zeitschrift für angewandte Chemie.
Zeitschrift für anorganische Chemie.
Zeitschrift des deutsche Geologische Gesellschaft.

The complete list of current periodicals in the library and publications received from societies and government sources, revised to the end of 1905, is here given:—

American Association for the Advancement of Science.
American Electrochemical Society.
American Engineer and Railroad Journal.
American Foundrymen's Association.
American Geologist.
American Institute of Architects.
American Institute of Electrical Engineers.
American Inventor.
American Iron and Steel Association.
American Journal of Science.
American Machinist.
American Manufacturer and Iron World.
American Museum of Natural History.
American Society for Testing Materials.
American Society of Civil Engineers.
American Society of Mechanical Engineers.
Annales des Mines de Belgique.
Annales des Mines.
Annalen für Gewerbe und Bauwesen.
Architekten und Ingenieur Vereins zu Hannover.
Asociacion de Ingenieros y Arquitectos de Mexico.
Association des Ingenieurs Sortis de l'ecole de Liège.
Association of Engineering Societies.
Australasian Institute of Mining Engineers.
Australian Mining Standard.
Austria Ackerbauministerium.
Die Bergakademie zu Clausthal.
Bibliographie mensuelle des Sciences et de l' Industrie.
Black Diamond.
Boletin de Cuerpo de Ingenieros de Minas de Peru.
Boletin del Ministerio de Obras Publicas, de Argentine Rep.
Boletin de la Secretaria de Fomento.
Boletin des Minas, Peru.
Boston Public Library.
Boston Society of Civil Engineers.
Bowdoin College Library.
Brass World and Platers Guide.
British Columbia Mining Record.
British Guiana. Department of Lands and Mines.
British Iron Trade Association.
British Museum (Mineral Department).
Bucherei des Kaiserlichen Patentamts.
Bureau of Mines, Victoria.
California Academy of Sciences.
California Journal of Technology.
California Miner's Association.
California State Mining Bureau.

Canadian Institute.
Canadian Mining Institute.
Canadian Mining Review.
Canadian Patent Office.
Canadian Society of Civil Engineers.
Carnegie Library of Pittsburgh.
Cassier's Magazine.
Chamber of Mines of Victoria.
Chemical and Metallurgical Society of South Africa.
Chemical News and Journal of Physical Science.
Chemiker-Zeitung.
Coal Trade Journal.
Colliery Guardian.
Colorado School of Mines.
Columbia University Library.
Comité des Forges de France.
Commissão do Servico Geologico de Portugal.
Conservatoire National des Arts et Métiers.
Consular Reports, Department of Commerce and Labor, U. S.
Cornell University Library.
Dartmouth College.
Deutsche Chemische Gesellschaft.
Deutscher Leseverein under K. K. Bergakademie.
Durham College of Science.
L'Echo des Mines and de la Metallurgie.
Economic Geology.
Edinburgh Geological Society.
Eisen Zeitung.
Electrochemical and Metallurgical Industry.
Electro-Chemist and Metallurgist.
L'Electrochimie.
Elektrochemische Technik.
Elektro-Chemische Zeitschrift.
Engineer.
Engineering.
Engineering Association of New South Wales.
Engineering Association of the South.
Engineering and Mining Journal.
Engineering Magazine.
Engineering News.
Engineering Press Monthly Index Review.
Engineering Record.
Engineering Review.
Engineering Standards Committee.
Engineers Club of Philadelphia.
Engineers Society of Western Pennsylvania.
Field Columbian Museum.
Fortschritte der Elektrotechnik.
Forestry and Irrigation.
Foundry.
Franklin Institute.
General Electric Company.
Geological and Natural History Survey of Connecticut.
Geological Society of America.
Geological Society of London.
Geological Society of South Africa.
Geological Survey of Alabama.
Geological Survey of Canada.
Geological Survey of Georgia.
Geological Survey of India.
Geological Survey of Louisiana.
Geological Survey of New Jersey.
Geological Survey of New Zealand.
Geological Survey of Ohio.
Geological Survey of Vermont.
Giesserei-Zeitung.
Glückauf.
Great Britain Mineral Statistics Branch.
Great Britain Patent Office.
Harvard University.
Historical and Scientific Society of Manitoba.
Imperial Geological Survey, Japan.
Imperial Institute of the United Kingdom.
Imperial University, Engineering College, Japan.
Indian Engineering.
(De) Ingeneiur.
L'Industrie Electro-Chimique.
Institut Royal Géologique de Suede.
Institut des Mines, Russie.
Institution of Civil Engineers.
Institution of Electrical Engineers.
Institution of Engineers and Shipbuilders in Scotland.
Institution of Mechanical Engineers.
Institution of Mining and Metallurgy.
Institution of Mining Engineers.
Institution of Naval Architects.
Instituto Géologica de Mexico.
International Bureau of American Republics.

Iowa Geological Survey.
Iron Age.
Iron and Coal Trades Review.
Iron and Steel Institute.
Iron and Steel Magazine.
Iron and Steel Trades Journal.
Ironmonger.
Jaarboek van het Mijnwezen.
Jahrbuch der K. K. Bergakademie zu Leobren und Pribram.
Jahrbuch der Königliche Geologische Landesanstalt.
Jahrbuch der K. K. Geologischen Reichsanstalt.
Jern Kontorets Annaler.
John Crerar Library.
John Hopkins University.
Journal of the American Chemical Society.
Journal de l'Electrolyse.
Journal of Geology.
Journal of U. S. Artillery.
Junior Institution of Engineers.
Kentucky Geological Survey.
Kings College.
Königliche Bergakademie zu Freiberg.
Königliche Oberbergamt zu Breslau.
Lake Superior Mining Institute.
Lead and Zinc News.
Lehigh University.
Library of Congress.
Library of Museum of Comparative Zoology, Harvard University.
Library of Parliament, Ottawa, Can.
Liverpool Engineering Society.
Machinery.
McGill University.
Manchester Association of Engineers.
Manchester Geological and Mining Society.
Maryland Geological Survey.
Massachusetts Institute of Technology.
Mechanics' Institute Library, San Francisco.
Metal Industry.
(Die) Metallarbeiter.
Metallurgie, Halle, Germany.
(La) Metallurgie, Paris, France.
Michigan College of Mines.
Michigan Geological Survey.
Military Service Institution.
Mineralogical Society.
Mines and Minerals.
Mining.
Mining Bureau, Manila, Philippine Islands.
Mining Engineering.
Mining Institute of Scotland.
Mining Journal, Railway and Commercial Gazette.
Mining Magazine.
Mining Reporter.
Mining Review and Metallurgist.
Mining and Scientific Press.
Mining Society of Nova Scotia.
Mining World.
Missouri Geological Survey.
Missouri School of Mines and Metallurgy.
Mittheilungen der K. K. Technologischen Gewerbe Museums in Wien.
Le Mois Scientifique et Industriel.
Modern Mexico.
Mysore Geological Department, India, Memoirs.
National Geographic Magazine.
New South Wales, Department of Mines.
New York Academy of Sciences.
New York Public Library.
New York State Library.
New Zealand Institute.
New Zealand Mines Record.
(Den) Norske Ingenior-og Arketekt Forening og den Polytekniske Forening.
North Carolina Geological Survey.
North Dakota Geological Survey.
North of England Institute of Mining and Mechanical Engineers.
Nova Scotian Institute of Natural Science.
Oesterreichische Zeitschrift für Berg und Hüttenwesen.
Oesterreichische Ungarische Montan- und Metallindustrie Zeitung.
Official Year Book, New Zealand.
Ohio State University.
Ontario Department of Mines.
Ores and Metals.
Page's Weekly.
Peabody Institute.
Philadelphia Commercial Museum.
Pittsburgh Library Association.
Polytechnic Institute.
Providence Public Library.

Queensland Department of Mines.
Queensland Government Mining Journal.
Queen's Quarterly.
Railway and Engineering Review.
Rassegna Mineraria.
Réale Comitato geologico d'Italia.
Rensselaer Polytechnic Institute.
Revista Minera.
Report of the Chief Inspector of Mines in India.
Report of the Department of Geology and Natural Resources of Indiana.
Report of the Inspector of Mines of Nova Scotia.
Report of Montana State Mine Inspector.
Revue de Mecanique.
(La) Revue de Métallurgie.
(La) Revue Mineralurgique.
La Revue Technique.
Revue Universille des Mines.
Rhodesia Chamber of Mines.
Royal Society of New South Wales.
Royal Society of Victoria.
Russian Imperial Tech. Society.
School of Mines, University of Minn.
School of Mining, Kingston, Canada.
Science.
Science Abstracts.
Sheffield Scientific School.
Smithsonian Institution.
Sociedad Cientifica "Antonio Alzate."
Sociedad Geologica Mexicana.
Sociedad Nacional de Mineria.
Societa Toscana di Scienze Naturali.
Société d'Encouragement pour l'Industrie Nationale.
Société Chimique de Paris.
Société Geologique de France.
Société Geologique de Belgique.
Société Geologique du Nord.
Société de l'Industrie Minerale.
Société des Ingenieurs Civils de France.
Society of Arts.
Society of Chemical Industry.
Society of Engineers.
South African Association of Engineers.
South African Engineering.
South African Mines, Commerce and Industries.
South African School of Mines.
South Carolina Geological Survey.
South Dakota School of Mines.
Stahl und Eisen.
Staffordshire Iron and Steel Institute.
State Library of Massachusetts.
State University of Iowa.
Statistisches Jahrbuch der Kaiserliches Statistisches Amt.
Stevens Indicator.
Tasmanian Secretary for Mines.
Technical World.
Technische Hochschule, Library.
Technische Literatur.
Technology Quarterly.
Teknisk Tidskrift.
Teknisk Ugeblad.
Tekniske Forening Tidsskrift.
Transvaal Department of Mines.
L'Union des Charbonnages.
U. S. Bureau of Standards.
U. S. Census Office.
U. S. Department of Agriculture.
U. S. Engineers School.
U. S. Geological Survey.
U. S. Mint.
U. S. Naval Institute.
U. S. Official Postal Guide.
U. S. Ordnance Department.
U. S. Patent Office.
U. S. War Department.
University Geological Survey, Kansas.
University of Alabama.
University of Arizona.
University of California.
University of Illinois.
University of Michigan.
University of Nebraska.
University of Oregon.
University of Otago.
University of Pennsylvania, Science Department.
University of Tennessee.
University of Texas.
University Library of Upsala.
University of Wyoming.
Vassar Brothers Institute.
Verein deutscher Eisenhüttenleute.
Verein Deutscher Ingenieure.
Vereins für die bergbaulichen Interessen im Obergamtsbezirk Dortmund.
Washington Geological Survey.
Washington University.
West of Scotland Iron and Steel Institute

Western Australia Department of Mines.
Western Railway Club.
Western Society of Engineers.
Wisconsin Geological and Natural History Survey.
Worcester Polytechnic Institute.
Yale University.
Yorkshire College.
Zeitschrift für Angewandte Chemie.
Zeitschrift für Anorganische Chemie.
Zeitschrift für Bergrecht.
Zeitschrift für das Berg-hütten und Salinen-Wesen im Preus. Staate.
Zeitschrift für Elektrochemie.
Zeitschrift für Praktische Geologie.

The *Iron Trade Review* was dropped in August, 1905.

Stone was discontinued in 1904; no longer published.

Brazilian Mining Review ceased its publication in May, 1904.

Technics ceased its publication in August, 1905.

American Geologist was incorporated with *Economic Geology* in January, 1906.

Berg und Hüttenmännische Zeitung was incorporated with *Glückauf* in January, 1905.

Telephone Magazine was merged in *Telephony* in August, 1905.

I would emphasize the great need in the library of modern authorities on inorganic and metallurgical chemistry, mineralogy and crystallography.

Respectfully submitted,
L. ELIZABETH HOWARD.

JANUARY 16, 1906.

Volumes Lacking.

The following volumes are needed to complete sets in the library:

Berg- und Hüttenmännische Zeitung, volumes i. to xxi., inclusive.

NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS, *Transactions*, volumes xxiii. to xxvi., inclusive.

Stahl und Eisen, Nos. 1, 2, 3 and 4 of vol. i.; Nos. 8, 9, 11 and 12 of vol. ii.; and indexes to vols. i., ii. and iii.

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[SECRETARY'S NOTE.—The fact that this well-known manual has reached a ninth edition is strong evidence of its continued usefulness and popularity. The volume contains a considerable amount of valuable new matter, and is arranged and indexed in such a way as to be convenient for both the student and the practical analyst. Of the seven parts in which it is divided, the first four treat of General Principles; Alkalimetry; Analysis by Oxidation or Reduction; and Analysis by Precipitation. The remaining three deal with the determination of the different metals, the examination of inorganic and organic compounds, waters and gases. There are also numerous tables of constants and formulas for use in practice.—R. W. R.]

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[SECRETARY'S NOTE.—This book is a compilation of numerous articles in the *Engineering and Mining Journal*, stating the cost of mining and milling in many parts of the world, and discussing such cognate subjects as the valuation of mines, etc. Mining engineers are aware that trustworthy information in this department is the most difficult of all to obtain. Mr. T. A. Rickard has intelligently selected and edited this collection of such contributions, thereby making a very useful volume for convenient reference, as well as for the general guidance and instruction of practicing experts.—R. W. R.]

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[SECRETARY'S NOTE.—Concerning this admirable book, the following remarks, taken from a more extended review by Dr. Joseph Struthers, published in *Science*, January 12, 1906, are quoted with hearty concurrence.—R. W. R.

"This volume, which is the English translation by Professor Louis of Dr. Schnabel's classic work, needs but the mention to declare its excellent merit, so widely known are both author and translator. The first German edition of Dr. Schnabel's admirable work of two volumes appeared in 1898, and was shortly afterward translated into English by Professor Louis. Both works were so well received that Dr. Schnabel issued a second edition, Vol. I. in 1902 and Vol. II. in 1904. The present book under review is Professor Louis' English translation of Vol. I. The English translation of Vol. II., which will also be made by Professor Louis, is expected to be published in 1906.

"The second edition has been largely rewritten, as may be appreciated by the increase of pages, from 873 to 1,123, and of illustrations, from 569 to 715. As a whole, the book is reliable, and should be in the hands of all students of metallurgy or metallurgical chemistry and all earnest workers in the practice of the art. The material is sufficiently comprehensive to give a thorough review of present metallurgical practices and the history of their development from early times."]

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METALLGESELLSCHAFT AND THE METALLURGISCHE GESELLSCHAFT, A. G. *12th Annual Issue, Comparative Statistics of Lead, Copper, Spelter, Tin, Silver, Nickel, Aluminium and Quicksilver.* 21, [6], 67 p. 4to. Frankfort-on-the-Main, 1905.

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lisch-chemische tabellen. Edition 3. Herausgegeben von Dr. Richard Börnstein und Dr. Wilhelm Meyerhoffer. xvi, 861 p. 4to. Berlin, 1905.

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MEMBERSHIP.

The following list comprises the names of those persons elected as Members or Associates, who duly accepted election during January and February, 1906:—

Members.

Frederick E. Allen,	Concepcion del Oro, Zacatecas, Mex.
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John L. Winter,	San Francisco, Cal.

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Robert P. Elliott,	Oaxaca, Oaxaca, Mex.
George F. Vollmer,	London, England.
Edward J. Walsh,	St. Louis, Mo.

NECROLOGY.

The following list comprises the names of members whose deaths have been reported to the Secretary of the Institute since January 1, 1905. It is doubtless incomplete, by reason of delay in sending such reports. Members are requested to read it carefully, and to call the attention of the Secretary to any omissions which they may discover.

Date of Election.	Name.	Date of Decease.
1880.	†Alexander B. Coxe, Drifton, Pa.,	January 23, 1906.
1882.	*Nicholas Lennig, Philadelphia, Pa.,	January 24, 1906.
1897.	*William Orr, Denver, Colo.,	November 20, 1905.
1900.	*Herman Poole, New York, N. Y.,	February 6, 1906.
1905.	*Albert W. Sales, Carbo, Sonora, Mex.,	January —, 1906.
1877.	†John Stanton, New York, N. Y.,	February 23, 1906.
1871.	*Samuel Thomas, Catasaqua, Pa.,	February 21, 1906.
1903.	*Harvey L. Williams, Bristol, Tenn.,	August 4, 1905.

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* Member. † Associate.

SECTION II.

TECHNICAL PAPERS AND DISCUSSIONS.

[The American Institute of Mining Engineers does not assume responsibility for any statement of fact or opinion advanced in its papers or discussions.]

A detailed list of the papers contained in this section is given in the Table of Contents, pages i and ii.

Comments or criticisms upon all papers given in this section, whether private corrections of typographical or other errors or communications for publication as "Discussions," or independent papers on the same or a related subject, are earnestly invited.

Errata.

The following corrections and additions to papers contained in *Bi-Monthly Bulletin No.* 7, January, 1906, were received too late for incorporation in the text of said papers; but will be introduced in their proper places in the volume of the *Transactions*. These corrections are here published in order to bring them promptly to the notice of the Institute.

Page. **Line.**

Cover, title-page and at the top of pages in the preliminary section "No. 1" should be "No. 7".

1. Bottom. For "Dr. P. H. Shimer" read "Dr. P. W. Shimer".

69. Fig. 3. "N" of compass-record should be "S". A new block for this illustration has been made as shown on p. xxxviii of this *Bulletin*.

78. 3 from bottom. For "slope" read "stope."

89. Fig. 2, small diagram in upper left-hand corner. Omit "use 50 ft. to 1″ scale". For "Thro' 250" read "Thro' 200". Add dotted line extending from upper right-hand corner of the square

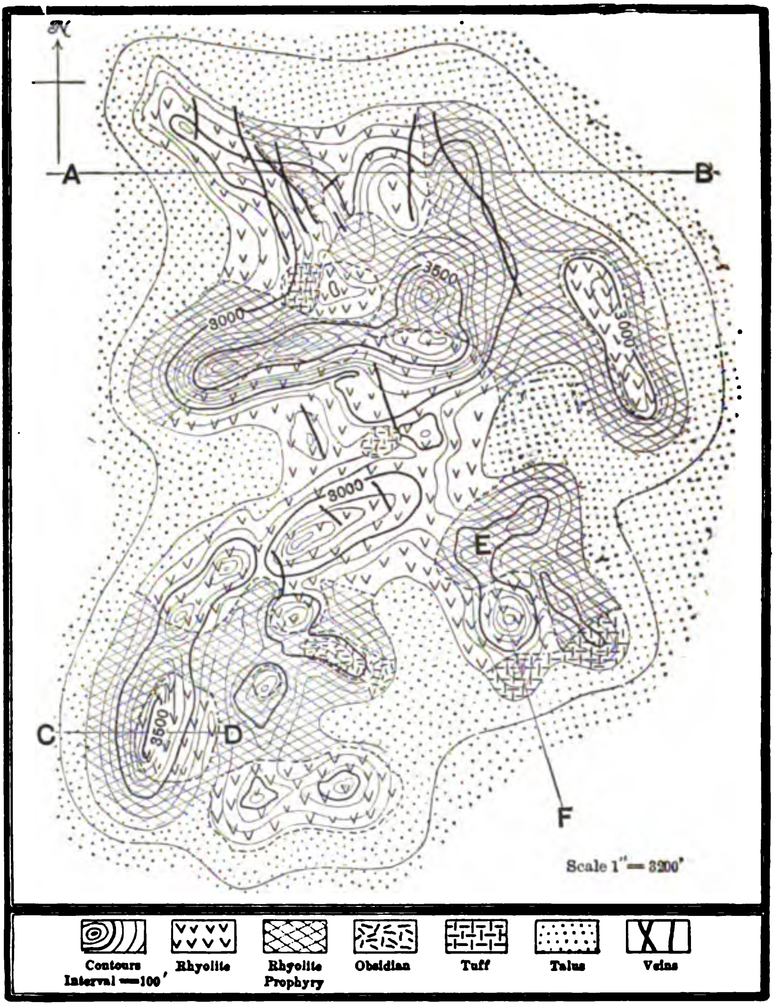
Page. Line.
to a point on the base line one-fifth the distance from the lower right-hand corner toward the left.
94. 15 from bottom. For "gold, 82.9" read "gold, 82.8".
94. 13 from bottom. Add "For brevity we shall represent the gold index,—Au, 82.8, and the silver index, Ag, 68.3". (These numbers are necessary to explain the sand-indexes given on Figs. 2, 5, and 6.)
100. Tables II., III., and IV., heading of last column. For "Net Profit" read "Total net Profit".
101. Table V., third column. For "Discharge Pulp Thickness" read "Discharge Pulp Thickeners".
103. Bottom. For "mill" read "mills".
106. 9. For "follows" read "followed".
106. 12. For "functions" read "function".
106. 10 from bottom. For "Butters" read "Gwynne".
107. 9 from bottom. For "96" read "0.96."
116. 1. For "90" read "1,200".
116. 4 from bottom. For "60 h.p." read "6 h.p."
127. 14. For "lost solution" read "last solution".
130. 23. For "precipitation" read "flow through the boxes".
131. 17. For "automatically" read "mechanically".

(In explanation of the changes in pages 89 to 131, it should be noted that the author, being abroad, did not have an opportunity to read either the galley or the page-proofs.—J. S.)

The following correction should be made in the present number of the *Bi-Monthly Bulletin.*

Page. Line.
286. 9. For "London, England," read "Scranton, Pa."

To face page 161. *Bi-Monthly Bulletin*, No. 8, March, 1906.



New map to replace Fig. 3 of Mr. Bateson's paper, The Mojave Mining-District of California, *Bi-Monthly Bulletin*, No. 7, January, 1906, p. 69.

SUBJECT TO REVISION.

[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

Lead- and Zinc-Deposits of the Virginia-Tennessee Region.

BY THOMAS LEONARD WATSON, VIRGINIA POLYTECHNIC INSTITUTE, BLACKSBURG, VA.

(British Columbia Meeting, July, 1905.)

CONTENTS.

PAGE
I. Introduction, . . . 140
II. Historical, . . . 140
III. General Geology, . . . 141
IV. Distribution of the Ores, . . . 143
V. Ores and Associated Minerals, . . . 144
  1. Lead-Ores,. . . . 144
    (a) Galenite, . . . 144
    (b) Cerussite, . . . 144
  2. Zinc-Ores, . . . 145
    (a) Sphalerite, . . . 145
    (b) Smithsonite, . . . 146
    (c) Calamine, . . . 146
    (d) "Buckfat," . . . 148
  3. Associated Ores, . . . 149
  4. Associated Minerals, . . . 149
    (a) Dolomite and Calcite, . . . 149
    (b) Fluorite, . . . 150
    (c) Quartz, . . . 152
    (d) Barite, . . . 152
VI. Alteration of the Lead- and Zinc-Ores, . . . 152
  1. Zinc-Ores, . . . 152
  2. Lead-Ores, . . . 153
VII. Mode of Occurrence, . . . 153
  1. Sulphide Ores, . . . 153
  2. Oxidized Ores, . . . 156
VIII. Paragenesis and Association, . . . 157
IX. Secondary Enrichment, . . . 160
X. Relation of the Ores to Geologic Structure, . . . 162
XI. Petrography, . . . 166
XII. Weathering, . . . 168
XIII. Age,. . . . 172
XIV. Origin of the Ores, . . . 172
XV. Virginia Deposits, . . . 174
XVI. Tennessee Deposits, . . . 181
  1. Introductory Statement, . . . 181
  2. Description of the Mines, . . . 182
    (a) Lead Mine Bend Area, Union County, . . . 182
    (b) Straight Creek Area, Claiborne County, . . . 187

(c) Holston River Area, Knox and Jefferson Counties, . . 188
(d) Jefferson City (Mossy Creek), ... 188
(e) New Market, ... 189
(f) Loy, ... 190
(g) Mascot, ... 191
(h) McMillan, Caswell and Loves Creek, . . , . . 192
(i) Other Localities, ... 192
XVII. General Conclusions Regarding the Ores, ... 193
XVIII. Bibliography, ... 194

I. INTRODUCTION.

THE results embodied in this paper are based on a careful field- and laboratory-study of the lead- and zinc-deposits of the Virginia-Tennessee district, begun in the latter part of the summer of 1904 and completed in the spring of 1905, preparatory to the publishing of a State report on them. A separate description of the individual deposits in Virginia is purposely omitted, since I have already described them in considerable detail in a State report.[1] The Tennessee deposits are described here in some detail for the reason that no detailed record of them has yet been published. Practically, this paper summarizes the results obtained from a study of the geology of the ore-deposits of the district as a whole. (I had the pleasure of visiting the deposits of Virginia and Tennessee with Dr. H. Foster Bain of the U. S. Geological Survey, in April, 1905. Figs. 21 and 22 are from photographs taken by Dr. Bain.)

II. HISTORICAL.

The first authentic records of lead-mining in Virginia date back more than 150 years, and the old lead-mines at Austinville, on New river in Wythe county, Va., were the first to be worked. Colonel Chiswell, a native of Wales, and one of the earlier adventurers in southwestern Virginia, was one of the first operators of the Austinville mines. Chiswell's operations at Austinville commenced in the year 1750, and closed shortly after the beginning of the Revolutionary War, in the year 1776, covering a period of about 25 years. From that time to the present, mining has been carried on almost continuously in the Virginia area.

For many years after the Virginia mines were operated, mining was confined exclusively to the lead-ores. The zinc-ores seem not to have been recognized at the Austinville mines until some time during the Civil War, when several tons were shipped to the smelting-works at Petersburg, Va.

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[1] Lead- and Zinc-Deposits of Virginia, *Bulletin No.* 1, *Geological Survey of Virginia*, 159 pages (1905).

Zinc-ores were first discovered at Bertha, near Austinville, in Wythe county, Va., during the year 1866. Mining of zinc-ores in Virginia properly dates from the opening of the mine at Bertha in 1879, at which time a small shipment of ore was made to Providence, R. I. The metal obtained from these ores proved to be of such rare purity that attention was directed at once to them, and a smelting-plant was built at Pulaski, Va., which was later remodeled and enlarged, and it is owned and operated at present by the Bertha Mineral Co. The "Bertha" spelter is of exceptional purity and has a world-wide reputation.

The records seem less complete for Tennessee than for Virginia. So far as I have been able to ascertain, the mines northeast of Knoxville, at Jefferson City (Mossy Creek), were the first to be opened in Tennessee (1858), but they were not worked until the year 1866 or 1868. Not until the year 1881, however, was serious mining begun in the Tennessee area. When zinc-ore was first discovered at Mossy Creek, in 1858, several thousand pounds of the ore are reported to have been shipped to the New Jersey zinc-works at Newark for testing. The later development of these mines in 1868 was the result of the test on the above shipment of ore.

III. General Geology.

Only those features of the general geology, which are essential to the understanding of the ore-deposition, will be considered here. The rocks included within the limits of the zinc- and lead-region of Virginia-Tennessee range from Lower Cambrian to Carboniferous in age. They are, without exception, of sedimentary origin; and include shales, sandstones, conglomerates and limestones, presenting considerable variety in composition and in appearance. They have been more or less metamorphosed, and in consequence are considerably changed, as a rule, both lithologically and structurally.

The ore-bearing formation in Virginia is the Shenandoah limestone, and in Tennessee its equivalent, the Knox dolomite, of Cambro-Ordovician age. The formation is a magnesian limestone, dark to light gray or nearly white in color, usually fine-grained and massive, and containing much chert distributed through parts of it in the form of nodules and layers. Over large areas, especially in Tennessee near Clinch and Powell rivers, some layers are coarsely crystalline, in fact they are marble. Wide variation in composition is noted from slight siliceous marble to calcareous sandstone.

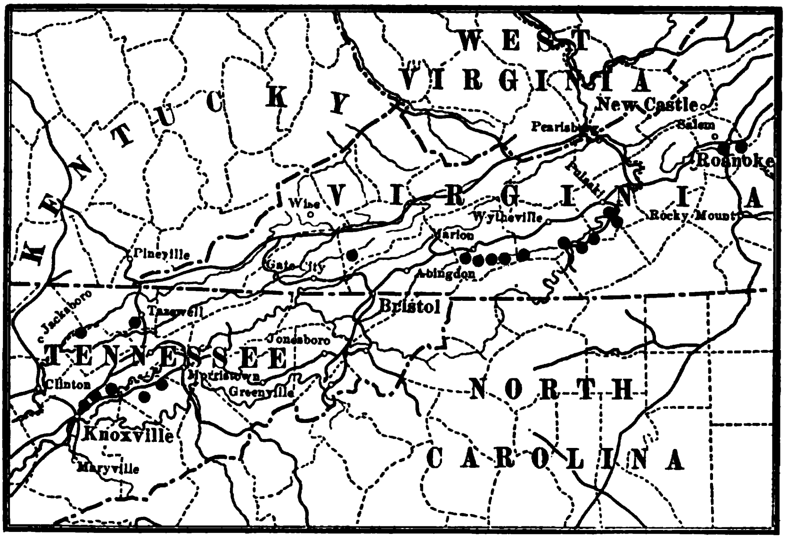
Folds and faults characterize the entire area of the Great Valley of the Virginia-Tennessee district. The folds have a general trend paralleling approximately the axis of the valley, which is NE–SW. in direction. The dips on the western side of the anticlines are frequently vertical, and in places overturned, and many of the folds have been compressed until broken. In the Tennessee area, Keith says that the dips range from flat to vertical and to 50° overturned. The usual dip on the southeast side of a fold is from 30° to 45° to the southeast. The faults are associated with the anticlinal folds, the breaks occurring usually on or near the northwestern side of the anticlines. The faults are of the over-thrust type, with the fault-planes usually dipping from 30° to 50° SE., with an estimated displacement, by Keith, in some of the faults of the Tennessee area, of nearly 3 miles. The faulted zone is usually characterized by much brecciation, and it is along these zones that localization and concentration of the lead- and zinc-ores have taken place.

The Appalachian valley has been a land-area since early Mesozoic time, during which time the field-evidence indicates several periods of uplift, followed by intervals of quiescence. The periods of quiescence, which followed each uplift, were sufficiently long to enable the streams to establish a system of base-levels over the entire region; and the region was also stationary for a time sufficient to admit of the inter-stream areas being lowered to an approximately uniform level. The harder and more resistant rocks, such as sandstone and quartzite, were never entirely reduced, but they marked partly unreduced residuals, which stand in relief above the general level of the erosion-plane.

Accordingly, evidence favoring several periods of base-leveling and planation is recorded over the area. The oldest and most extensive peneplane was probably formed in Cretaceous time. Subsequent uplifts were followed by shorter periods of quiescence, which record other peneplanes cut during the Eocene and Neocene periods.

IV. DISTRIBUTION OF THE ORES.

Geographically, the ores are confined to the valley region of southwestern Virginia and its equivalent in eastern Tennessee, extending from Roanoke, Va., southwestward to Knoxville, Tenn., as indicated on Fig. 1. Isolated deposits of the ores are found further south and west in Tennessee. Not all of the above area contains workable deposits of lead and zinc, but, up to the present time, the productive areas are confined within the limits of two or three counties in each State. Numerous isolated single prospects have been opened, away from the productive centers within the valley region of both States.



Scale, 1 inch = 120 miles.

FIG. 1.—MAP OF SOUTHWESTERN VIRGINIA AND EASTERN TENNESSEE, SHOWING DISTRIBUTION OF LEAD- AND ZINC-ORES. LEAD- AND ZINC-DEPOSITS INDICATED BY HEAVY DOTS.

Geologically, the ores are confined to a single formation, magnesian limestone of Cambro-Ordovician age, known as the Shenandoah limestone in Virginia, and the Knox dolomite in Tennessee. The Shenandoah limestone is correlated with the Knox dolomite, and it includes, in addition, at least 1,500 ft. of Cambrian strata beneath the Knox dolomite.

V. THE ORES AND ASSOCIATED MINERALS.

The minerals of the lead- and zinc-region in Virginia and Tennessee are not numerous in species, but they are confined chiefly to a few of the commoner forms. They include (1) the original sulphide forms, sphalerite, galenite, pyrite and, in one or two places, chalcopyrite; and (2) the secondary or oxidized forms which have been derived from the original sulphides and occur in the residual decay of the limestone. These include calamine, smithsonite, cerussite and limonite.

The associated non-metallic minerals, named in the order of their importance, are dolomite, calcite, barite, fluorite and quartz. Of these, dolomite and calcite constitute the principal ones, and they occur in vastly the largest amount. Barite, fluorite and quartz have not been observed in the Tennessee area, but they are confined to several places in the Virginia area.

1. *The Lead-Ores.*

(a) *Galenite.*—The principal occurrence of galenite is in association with the zinc-ores in the zinc-mines. The association of galenite and sphalerite seems to be more general in Virginia than in Tennessee. At a number of the zinc-mines in Tennessee and at a smaller number in Virginia, galenite is practically absent; while in others it occurs in fairly large amounts in intimate association with the sphalerite. It is reported to be the principal ore at several places in Tennessee. Its usual occurrence is granular and massive-granular, less frequently in the form of crystals. Selected specimens from the Austinville lead- and zinc-mines, Wythe county, Va., gave the following results on analysis:

Lead (Pb),	73.89	equivalents		
Zinc (Zn),	9.31		PbS,	85.29
Iron (Fe),	0.22		ZnS,	13.87
Sulphur (S),	16.20		FeS_2,	0.46
Silica (SiO_2),	0.54			
Total,	100.16			

(b) *Cerussite.*—Cerussite has been found, in more than a trace, only at one locality, namely, the Austinville mines in Wythe county, Va., where it is not an altogether uncommon ore among the altered forms. During the period of early mining in East Tennessee, cerussite was noted as one of the altered ores occurring in the residual decay in several of the mines. It occurs distributed through the residual clays of the limestone as stringers and small irregular masses. The earthy form greatly predominates, this clayey admixture being readily identified by its weight. Crystals grouped in clusters and aggregates of white and light grayish color distributed through the clay are not uncommon. It also occurs as a white, powder-like coating on the crystals and masses of granular galena.

2. *The Zinc-Ores.*

(a) *Sphalerite.*—This mineral, constituting the most important ore over much of the Virginia-Tennessee district, was the original zinc-mineral from which the secondary zinc-ores, concentrated above ground-water level, have been derived. It is found usually below the level of ground-water, and, in some of the mines not yet worked to this depth, it has been found but sparingly. It varies in color from yellow, through brown, to nearly black; the black color being due to impurities, particularly iron. In some of the larger mines sphalerite is associated with much galenite, in places; some pyrite, and very occasionally with scant chalcopyrite.

The occurrence of sphalerite is in the form of disseminated grains, masses and stringers, in the magnesian limestone; and in similar form, but mostly as stringers, in quartz-fluorite lenses intercalated in a crinkled, talcose schist, in Albemarle county. At Cedar Springs, Wythe county, and Rye Valley, Smyth county, Va., the blende is of exceptional purity, as indicated in the analyses below. It is of yellow color, massive in form, with perfect cleavage, but not preserving outward crystal form. At other localities in Virginia and Tennessee, the blende is less massive in form, and occurs mostly as disseminated grains.

The character of the blende over the Virginia area is indicated in the analyses below from selected pieces collected from the mines in Albemarle, Wythe and Smyth counties.

	Austinville, Wythe County. Per Cent.	Cedar Springs, Wythe County. Per Cent.	Rye Valley, Smyth County. Per Cent.	Albemarle County. Per Cent.
Zinc, . . .	65.01	66.76	66.94	62.11
Sulphur, . .	31.93	33.44	33.26	34.45
Iron, . . .	1.94	0.50	0.30	3.44
Lime, . . .	0.08	trace	trace	0.05
Magnesia, . .	none	trace	trace	none
Silica, . . .	0.33	0.10	0.08	0.26
Total, . .	99.29	100.80	100.58	100.31
Zinc sulphide, .	96.94	99.56	99.86	92.70

(b) *Smithsonite.*—In some of the mines, especially in Virginia, smithsonite forms a fairly important ore of zinc. It occurs in the residual clays derived from the magnesian limestone, concentrated usually in the bottom portions of the clays, and resting immediately on the irregularly weathered surface of the limestone, as is shown in Figs. 2 and 3. It is intimately associated with calamine.

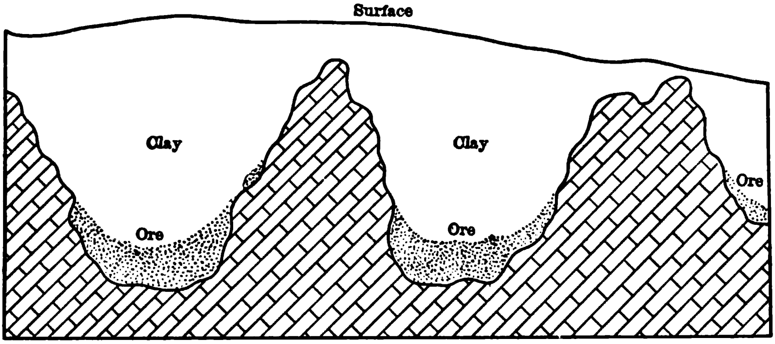
Smithsonite occurs both in the granular and earthy form, principally the latter, as crystalline incrustations, and as a porous or spongy material with the cavities frequently filled with a powdery and earthy form of the ore. In color it varies from light gray, through yellow, to brown, according to the impurities present.

The calculated amounts of smithsonite and calamine, from analyses made by F. P. Dewey on specimens of the ore of the Falling Cliff zinc-mine at Bertha, Va., gave the following results:

	I. Per Cent.	II. Per Cent.
Smithsonite, ...	75.52	79.99
Calamine, ...	22.22	12.05

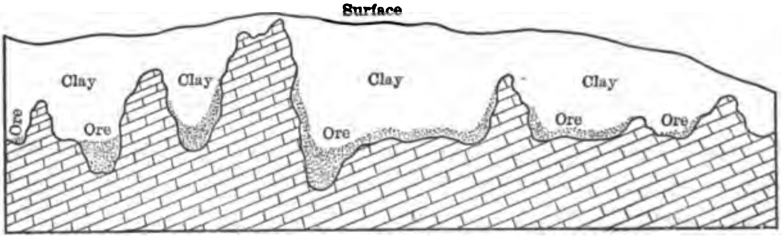
(c) *Calamine.*—Calamine formed originally the principal secondary ore of zinc mined in the district. It is much more abundant than smithsonite. In occurrence it is closely similar to that of smithsonite, with which it is intimately associated. It is indeed very difficult, and in some cases impossible, to separate the two ores, so intimately admixed are they.

Calamine occurs in the residual clays usually in the bottom portions immediately on and next to the irregular weathered surface of the underlying limestone, shown in Figs. 2 and 3. Beautiful white incrustations of the mineral, presenting both mammillary and stalactitic surfaces, have been observed in places between layers of the more solid massive ore. Granular massive and honey-comb forms of calamine were quite common. Much of the calamine formerly mined at Bertha is reported to have been in sheet form, rarely in contact with the limestone, but concentrated several inches away from the limestone surface, and having the intervening space filled with a mixture of loose powdery calamine and smithsonite.



Blocked area is limestone.

FIG. 2.—SECTION IN OPEN CUT AT THE AUSTINVILLE LEAD- AND ZINC-MINES, SHOWING THE RELATIONS OF THE SOFT ORE TO THE LIMESTONE "CHIMNEYS" AND THE RESIDUAL CLAY. AUSTINVILLE, WYTHE COUNTY, VA.



Blocked area is limestone.

FIG. 3.—SECTION IN OPEN CUT AT THE BERTHA ZINC-MINES, SHOWING THE RELATIONS OF THE SOFT ORE TO THE LIMESTONE "CHIMNEYS" AND THE RESIDUAL CLAY. WYTHE COUNTY, VA.

The following chemical analyses of specimens of calamine from the mines in Wythe county, Virginia, indicate the general character of the ore.

	I. Per Cent.	II. Per Cent.	III. Per Cent.
Zinc oxide,	67.88	67.42	67.15
Silica,	23.95	25.01	25.33
Water,	8.13	8.32	7.47
Total,	99.96	100.75	99.95
Sp. Gr.,	3.338	....	3.40

I. MacIrby, *Chemical News*, 1873, vol. xxviii., p. 272.
II. Genth, F. H., *Proceedings of the American Philosophical Society*, 1885, vol. xxiii., p. 46.
III. Jones, A., *Journal of the American Chemical Society*, 1892, vol. vi., p. 620.

Calculated amounts of calamine and smithsonite, from analyses made by F. P. Dewey on specimens of the ore from the Falling Cliff zinc-mine, at Bertha, Va., gave the following results:

	Per Cent.
Calamine,	88.52
Smithsonite,	3.26

(d) "*Buckfat.*"—Buckfat is the name applied by the miners to a mixture of clay with the minerals, calamine and smithsonite. It is not a definite mineral, but is a lean ore, generally too low in zinc to be profitably used in the present practice of smelting. The zinc-content shows wide variation, however, ranging oftentimes much higher than that given in the analysis below. It is both hard and soft, and is accordingly called by the miners "hard buckfat" and "soft buckfat." Its separation from the rich ores is effected by hand-sorting and by subsequent washing and jigging. The treatment practiced at the Bertha mines, Va., previous to the conversion of the ore into spelter, consisted in violently washing soft buckfat in water, and crushing and jigging the hard buckfat.

Heyward gives the following analysis of a zinc-bearing clay from the neighborhood of the Bertha mines, Virginia.

	Per Cent.
Silica,	37.38
Alumina,	24.67
Ferric oxide,	6.34
Zinc oxide,	12.10
Magnesia,	0.27
Potash,	0.47
Soda,	0.27
Water 100° C. —,	6.69
Water 100° C. +,	10.35
Total,	98.54

3. *Associated Ores.*

Over the Virginia area, iron-ores and manganese-ores, especially the former, are very abundant in some of the larger zinc-mines. The iron-ores have been somewhat extensively mined in places, and in several instances mines, formerly worked for zinc-ores, are now being worked for iron. Pyrite is rather a frequent associate of galenite and sphalerite in some of the Virginia mines. It occurs in the fresh limestone below the belt of oxidation. It is by no means uniformly distributed through the rock, but in places it is sufficiently concentrated to be noticeable, and rarely, if ever, is it present in quantity large enough to be hurtful to the lead- and zinc-ores. Limonite comprises the principal iron-ore mined in association with the zinc-ores. Hematite is less common than limonite. The black oxide of manganese frequently occurs in some of the mines, but at no place has it been found in quantity sufficiently large to attempt the saving of it.

4. *Associated Minerals.*

The associated minerals are limited both as to species and occurrence. Named in the order of their importance they are,—dolomite, calcite, fluorite, quartz and barite. Of these, dolomite and calcite comprise the minerals associated with the ores in the Tennessee area. In addition to these, which form the principal minerals in the Virginia area, fluorite, quartz and barite occur. Fluorite and quartz constitute the gangue minerals at the zinc- and lead-mine in Albemarle county, Va. Calcite occurs only sparingly at this mine, while fluorite is the dominant mineral. In the mines of southwestern Virginia dolomite and calcite comprise the dominant minerals, with some barite and less fluorite. Here, and over the Tennessee area, the dolomite and calcite fill the fractures between the magnesian limestone fragments in the form of crystalline masses, forming a limestone breccia. The relative proportions of cement (recrystallized calcite and dolomite) to rock fragments vary widely.

(a) *Dolomite and Calcite.*—These minerals occur intimately admixed in massive crystalline form, filling the fractures between the broken limestone fragments, which cement them together as breccia. They are prevailingly white in color, and frequently occur in perfect cleavable masses of the rhombohedral type. Numerous analyses of specimens of the calcite and dolomite collected over the Virginia-Tennessee district gave nearly pure calcium carbonate for the former, and a ratio of calcium to magnesium of 1 : 1 for the latter, which is the ratio of normal dolomite.

(b) *Fluorite.*—At the mines in Albemarle county, Va., fluorite, the predominant mineral, occurs in both large and small lenses in the crinkled schist, and it is usually of white color, though the violet shade is fairly common. This mineral has been sparingly found at several localities in southwestern Virginia in association with the metallic sulphides, but as yet it is unknown in the Tennessee area. In the Virginia mines it occurs in three forms:—distributed through and enclosed by the blende; distributed through the dolomite and calcite filling of the limestone breccia; and in association with dolomite and calcite, filling and lining small cavities in the limestone, as shown in Figs. 4, 5 and 6. Lastly, fluorite was sparingly noted

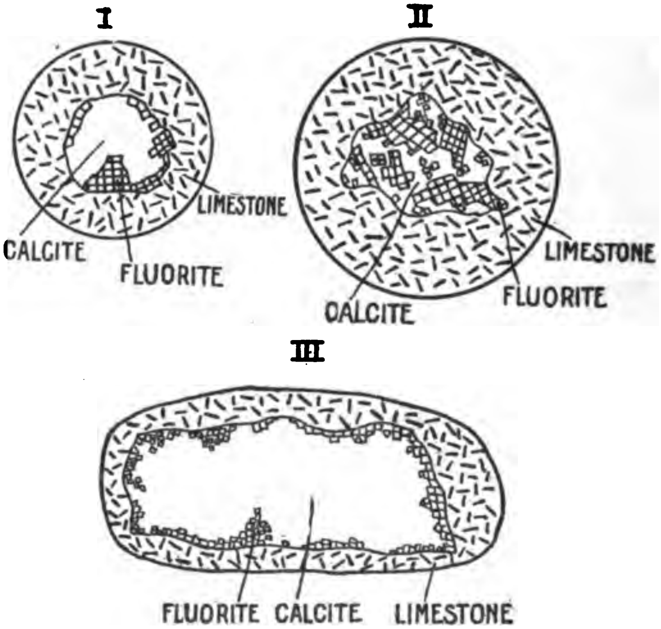


FIG. 4.—CAVITIES IN MAGNESIAN LIMESTONE FILLED WITH CALCITE AND FLUORITE, SHOWING THE RELATIONS OF THE TWO MINERALS TO EACH OTHER. MCCARTER PLACE, RYE VALLEY, SMYTH COUNTY, VA.

at the mine of the Rye Valley Mining Co., near Sugar Grove, Va., as a coating in association with calcite and dolomite on the slickenside surfaces and parting planes of the limestone.

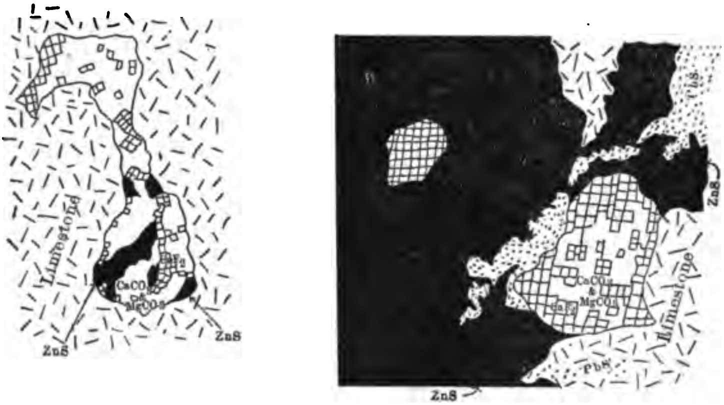


FIG. 5.—SKETCH, SHOWING RELATIONS OF SPHALERITE AND GALENA TO FLUORSPAR AND CALCITE-DOLOMITE. RYE VALLEY MINING CO., SUGAR GROVE, SMYTH COUNTY, VA.

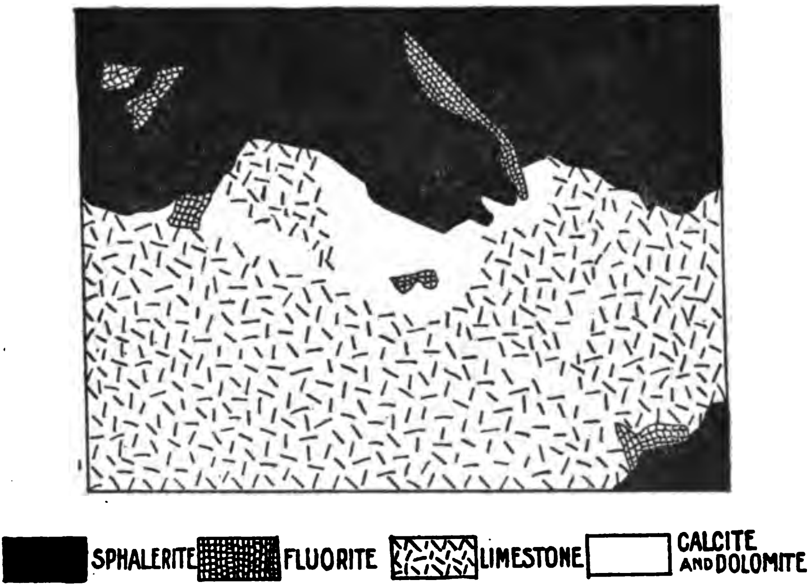


FIG. 6.—LIMESTONE BRECCIA FROM THE CEDAR SPRINGS ZINC MINING AND DEVELOPMENT COMPANY'S OPENINGS, SHOWING THE RELATIONS OF FLUORSPAR TO SPHALERITE, AND TO THE CALCITE-DOLOMITE FILLING. NATURAL SIZE. CEDAR SPRINGS, WYTHE COUNTY, VA.

(c) *Quartz.*—The mineral quartz is found in direct association with the zinc- and lead-ores only at the zinc- and lead-mine in Albemarle county, Va. It is admixed with fluorspar as fluorspar-quartz lenses, which contain the lead- and zinc-ores distributed through them. Quartz is very much less abundant than fluorspar. Quartz, in the form of chert, is abundantly distributed through the lead- and zinc-bearing magnesian limestone of southwestern Virginia and eastern Tennessee, but the chert is rarely or never seen in close association with the ores.

(d) *Barite.*—This mineral is common over the limestone region of southwestern Virginia, and it has been mined in several places, but it is not associated with the lead- and zinc-deposits except at two of the mines. It has been observed in small quantity at the Bertha zinc-mine, and it was very abundant at the mines of the New River Mineral Co., west of Ivanhoe. At the latter place a little of the blende was observed to be enclosed by the barite-filling of the limestone.

VI. THE ALTERATION OF THE LEAD- AND ZINC-ORES.

The important secondary ores comprise calamine, smithsonite and cerussite, which have been derived from the original sulphides, galenite and sphalerite, by oxidation, carbonation, silication and hydration above or near ground-water level. Only the oxidized or secondary ores have been mined, but every preparation is now being made to mine the original sulphide ores in the fresh limestone.

1. *The Zinc-Ores.*—Below the ground-water level, in the fresh limestone, the mineral form of the zinc-ore is the sulphide, sphalerite. Above this level, in the belt of residual decay, only the altered forms, the oxidized ores of zinc, are found,—calamine and smithsonite; the former always predominating. Smithsonite is found in larger quantity in some mines than in others. Unaltered sphalerite seems not to occur in the decay of any of the mines, but it is replaced instead by the two oxidized forms mentioned above.

Portions of the country-rock next to the bottom portions of the loose decay, originally containing grains and crystals of the sulphide ores, sphalerite and galenite, are now porous and open-textured in many places,—a condition resulting from the removal of the sulphides in solution. Frequently, where the alteration has been complete, the rock apparently is extremely cavernous and presents a typical honey-comb appearance. Yet in other places the ores have been observed in the limestone in various stages of oxidation, and the cavities left are either entirely vacant or are occupied by a film of iron oxide. In the process of alteration the oxidized ores may be removed a short distance, or they may remain practically in place; usually migration is indicated.

2. *The Lead-Ores.*—Like that of zinc, the mineral form of the lead in the fresh rock is the sulphide, galenite, admixed usually with sphalerite. In the belt of decay, more or less closely associated with the secondary zinc-ores, the oxidized form of lead is cerussite, which is present in very appreciable quantity in the Austinville mines in Wythe county, Va. In addition to the cerussite, more or less galenite occurs in the belt of weathering admixed with the secondary ores. Galenite being more difficultly oxidizable than the sulphides of zinc and iron with which it is associated, and being less soluble than the limestone in which it occurs, are circumstances which account chiefly for the presence of galenite in association with the secondary ores in the zone of weathering.

The cerussite is sometimes observed coating or incrusting the galenite, and occasionally it has been noted in small crystals on the galenite. In some specimens of the galenite not incrusted by the alteration-product, cerussite, the surfaces appear dull, and are much roughened, being pitted by etching. The same specimens, when broken, show the bright metallic luster of the unaltered galenite on the inside. A few specimens were noted which were apparently all cerussite, but, on breaking, they proved to be only partly altered; the outer portions of the original galenite being entirely coated with a variable thickness of the lead carbonate, and the inner part composed of fresh unaltered galenite. In still other specimens, limited to the zone of weathering, the alteration seemed complete, with no trace of the original sulphide indicated. Between these two extremes of alteration nearly all gradations were observed.

VII. MODE OF OCCURRENCE.

1. *The Sulphide Ores.*—The bulk of the sulphide ores belong to the disseminated replacement breccia type. As a rule, the

process of replacement has played an important part in the ore-formation, but in some instances very little replacement of the limestone by the ore is indicated. In the latter case the ore would be more properly designated a straight breccia type in which practically no replacement has occurred. On the other hand, the ore has originated at several places over the district largely through a replacement process.

The breccia is usually made up of sharp-angled fragments of the country-rock, magnesian limestone, cemented by a matrix of white crystallized calcite and dolomite and blende, with or without replacement of the limestone fragments. The breccia-zones are associated with faulting and folding. Not all parts of the breccia-zones are mineralized, but the ore is distributed at somewhat irregular intervals. Where mineralized, and so far as can be judged from developments, the ore continues with depth.

At Austinville, Va., clear crystallized calcite apparently does not occur, but the rock has been largely recrystallized, and small "eyes" of the dark, nearly unaltered, rock are distributed through the new recrystallized portion. Jointing is freely developed, and ore concentration and replacement of the recrystallized limestone by the ores have taken place along the bedding- and joint-planes, mostly where the two sets of planes intersect, forming large and well-defined ore-shoots. Similar bodies of sulphide ores are developed at the Straight Creek mine, near Tazewell, in Claiborne county, Tenn. As elsewhere explained, the process of mineralization at Austinville began, first by filling the fine cracks, and then extending into and replacing the anhedra of dolomite by ore along some crystallographic direction, as illustrated in Figs. 7 and 8.

Where occurring in the same mine, the blende and galenite are intimately admixed. Many parts of the limestone, both small and large, show all blende, with only here and there sparing dissemination of galenite through the rock, closely intermingled with the blende. Other parts of the limestone, usually much smaller in area, show a preponderance of galenite with little or no disseminated blende. The same relation holds true for the very small amount of pyrite present in the rock, which may be intermingled with the galenite or blende, or both. The relations between the galenite and blende in the limestone, as described above, are made plain in Figs. 9 and 29.

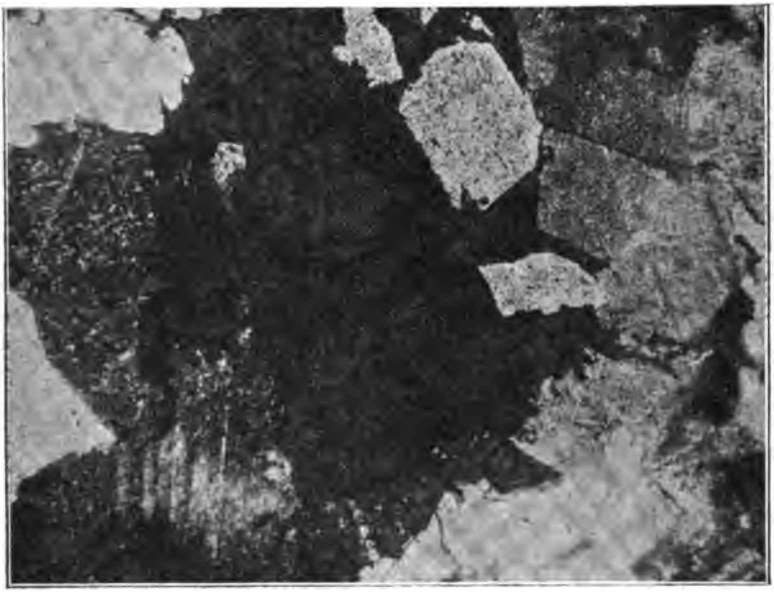


FIG. 7 (A).

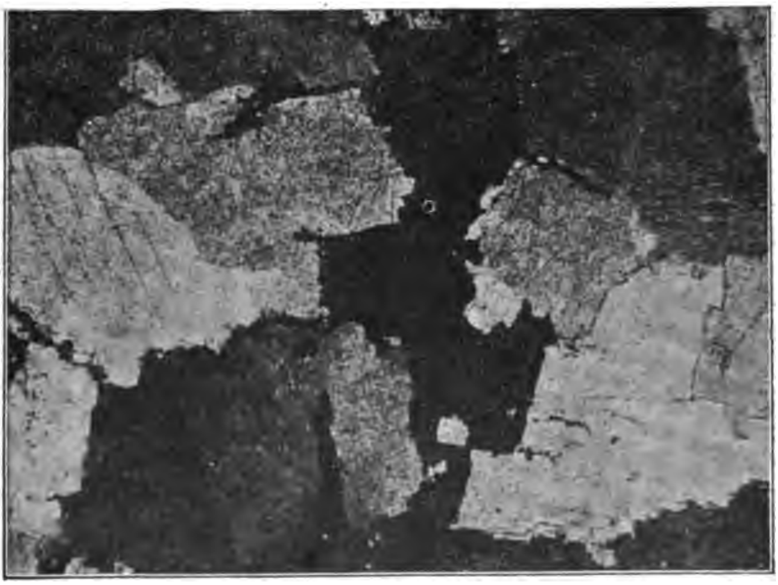


FIG. 8 (B).

PHOTOMICROGRAPHS OF THIN SECTIONS OF SULPHIDE ORE FROM AUSTINVILLE MINES, WYTHE COUNTY. MAGNIFIED 50 DIAMETERS; CROSS NICOLS. Black areas represent sulphide minerals. Shows crystalline character of limestone and its replacement by the sulphides. Re-entrant angles along margins of the sulphides and the spider-like arrangement of the sulphide areas, as a whole, are well shown.

2. *The Oxidized Ores.*—Where sufficient developments have been made, as in the mines of Wythe county, Va., the oxidized ores usually show much richness, and they are often concentrated in massive form as large irregular masses and layers. This is especially true of the calamine, which forms the dominant oxidized ore. So massive was the calamine in places in the old Bertha mines, that blasting is reported to have been necessary at the time for its removal.

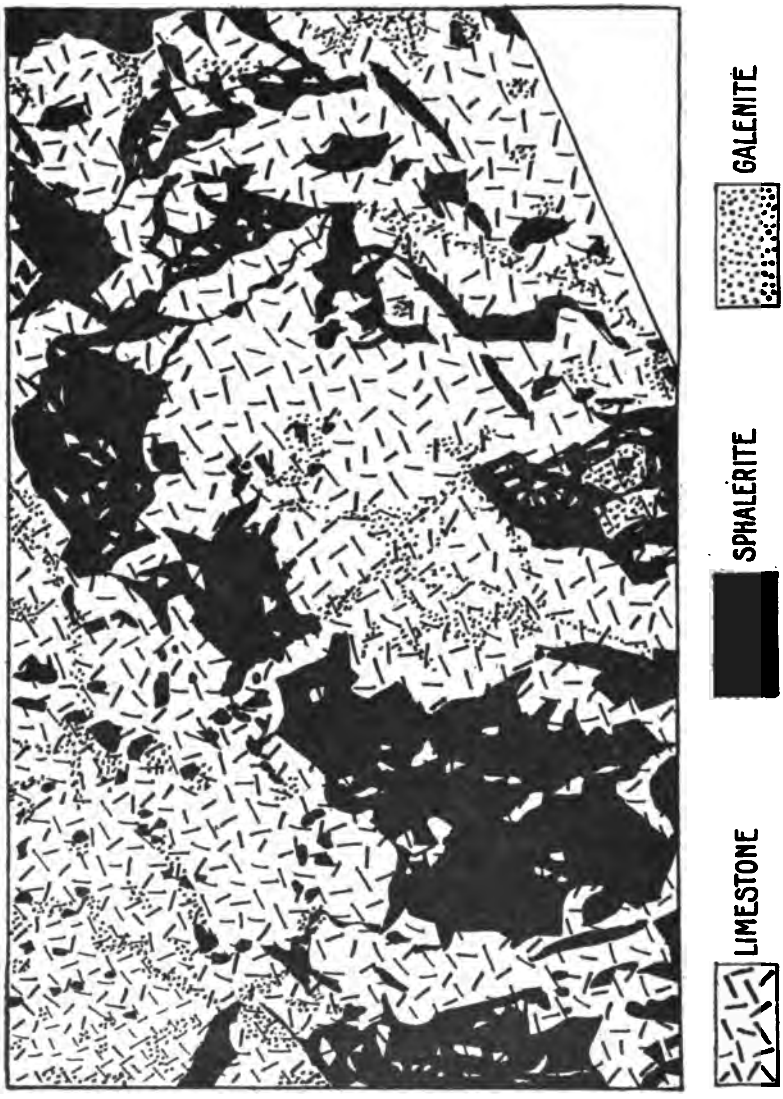


FIG. 9.—SPECIMEN OF TYPICAL ORE FROM AUSTINVILLE LEAD- AND ZINC-MINES, SHOWING RELATIONS OF SPHALERITE AND GALENITE TO EACH OTHER AND TO THE LIMESTONE. Natural Size.

Concentration of the oxidized ores has taken place principally at and near the bottom of the residual clays, closely hugging the irregular weathered surface of the limestone, as shown in Figs. 2 and 3. Frequently several inches separate the massive form of the ores, calamine and smithsonite, from the limestone. This space is filled, oftentimes, with a loose powdery form of admixed calamine and smithsonite. At times the partly decayed limestone, in pulverulent granular form, partly or entirely fills the space. Much galenite is intermingled in places with the concentrated calamine and smithsonite in the lower portion of the clays. Usually, when associated with the oxidized ores in the way mentioned, the galenite is observed to diminish in quantity upward more rapidly than the calamine and smithsonite.

Smithsonite, which is present in much smaller quantity than calamine, is admixed, as a rule, with the calamine, and both are concentrated in the basal portion of the clays next to the limestone surface. Cerussite occurs largely in stringer-form, penetrating the clays, and as a coating on the masses and nodules of galenite. The stringers of cerussite show considerable variation in thickness and extent, but in the larger ones a nearly vertical position in the clays is often assumed.

As a rule, the residual clays are highly ferruginous. Limonite composes the principal part of the clays in some of the mines, and it was derived, in part at least, from the oxidation of the original sulphide of iron, pyrite, disseminated through the limestone in association with galenite and sphalerite. It is usually of good grade, and it occurs so extensively in some of the mines formerly worked for zinc-ores, that attention is now given entirely to the mining of the iron-ore.

The relations between the ores, the limestone and the clays, as described above, are shown in Figs. 2 and 3.

VIII. PARAGENESIS AND ASSOCIATION.

No definite order of deposition of the original minerals could be positively determined. The metallic sulphides, lead, zinc and some iron, and the gangue minerals, seem to have been introduced and crystallized at about the same time. The three sulphides, when present, are usually so intimately mixed as to preclude any attempt at determining the order of deposition.

Variations in the association of the metallic sulphides and the gangue minerals, and the relations of these to the enclosing rock, are shown.

A common association is the more or less replacement of the country-rock on one or both sides of a fracture by the sulphides, and the filling of calcite and dolomite without metallic sulphides distributed through it. In places, the broken fragments of limestone are either partially or completely rimmed by narrow bands of sphalerite, as shown in Figs. 10 and 11. At times both forms of filling rudely resemble banding on a small scale, in which it appears that the sulphides were perhaps introduced somewhat in advance of the gangue filling. When it is remembered, however, that all gradations are observed between this form of filling and those stated next below, where the evidence seems conclusive for contemporaneous deposition, it seems reasonable to assume that deposition of the ores and the associated minerals for the district, as a whole, was made at about the same time. Moreover, cases are observed in which calcite and dolomite are entirely enclosed by the metallic sulphides and vice versa. Similar relations of fluorite to the sul-

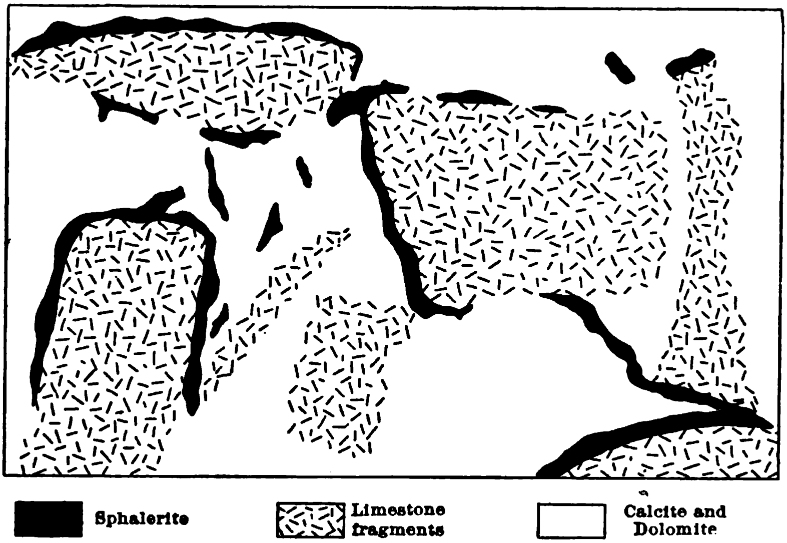


FIG. 10.—BRECCIATED LIMESTONE CEMENTED WITH CALCITE AND BLENDE. LIMESTONE FRAGMENTS PARTIALLY RIMMED BY BLENDE. SKETCHED FROM SECTION OF OPEN-CUT WALL, MOSSY CREEK MINES, JEFFERSON CITY, TENN.

phides, and fluorite to calcite and dolomite are observed. Fig. 6 shows that fluorite is entirely enclosed by the calcite-dolomite filling, and fluorite is also entirely enclosed by blende. Again, the filling of very small cavities in the limestone by fluorite and calcite in Rye Valley, Smyth county, Va., shows in some cases

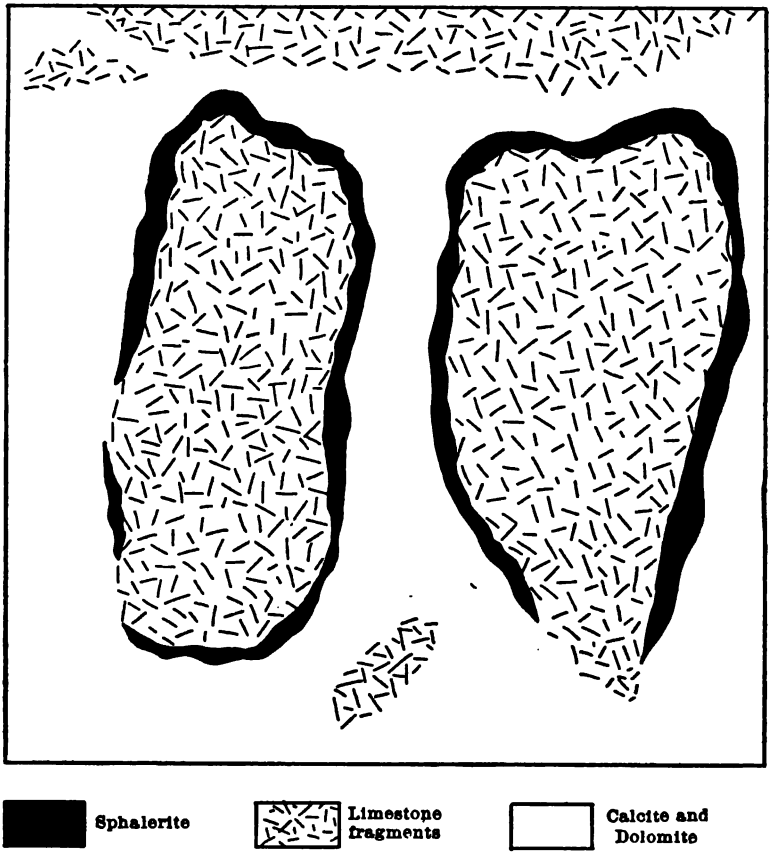


Fig. 11.—Brecciated Limestone, Showing Rims of Blende Around Limestone Fragments. Drawn from Face of Workings in Mossy Creek Mines, Jefferson City, Tenn.

a somewhat broken, irregular lining of the cavity by fluorite next to the limestone and the remainder filled in by calcite, as indicated in Fig. 4. This association of fluorite and calcite points to a filling of fluorite in advance of the calcite; but occurring immediately along side of this may be observed a similar cavity filled with intimately admixed fluorite and calcite from the walling to the center of the cavity, where no doubt exists of the simultaneous deposition of the two minerals.

Equally common, perhaps, is the filling of the fracture in the limestone by metallic sulphides and the gangue minerals, without any replacement of the limestone by the sulphides indicated. In this case the sulphide ores are distributed through the filling of calcite and dolomite. In still other cases the fracture may be filled for its entire width at intervals along its length with the sulphides, and the intervening spaces filled entirely with calcite and dolomite, or with a mixture of the gangue and sulphide minerals, as shown in Fig. 12.

Sufficient developments in the fresh limestone are lacking, upon which to base any statement of a grouping corresponding to a vertical order of succession of the dominant metallic sulphides. The idea prevails over the district that galenite is more abundant in the upper portions of the rock, and decreases in depth, followed by an increase of blende. So far as developments have gone, evidence is not entirely lacking to support this idea. At Austinville, Va., where mining has been more extensive in the fresh limestone than elsewhere, blende indicates an increase over galenite in depth, although much galenite occurs at the depth thus far reached.

Little or no blende is found within the zone of alteration at the Austinville mines, while galenite is by no means an uncommon mineral within this zone. This is due, however, not to the absence of blende originally in the fresh rock of this zone, but more to the readiness with which blende alters than galenite. Indeed, the large accumulations of the oxidized zinc-ores, calamine and smithsonite, found within the zone of decay, afford every evidence of the presence originally of much blende in the fresh rock of this level.

IX. SECONDARY ENRICHMENT.

The common evidences of secondary enrichment are wholly lacking in the Austinville mines, but the ore-bodies in the fresh rock are regarded as unmodified ores of primary deposition or of first concentration. Careful study shows the conditions to be against, rather than favorable to, secondary enrichment. Briefly stated, these are: (1) Recrystallization from solution and cementation of the rock below, resulting in the closing of the original spaces, which precluded the downward circulation of the waters. (2) The absence of lean sulphides necessary to produce precipitation. Sufficient pyrite in the limestone was lacking to precipitate zinc and lead as sulphides from their oxidized salts; but zinc-sulphide as blende was present in places

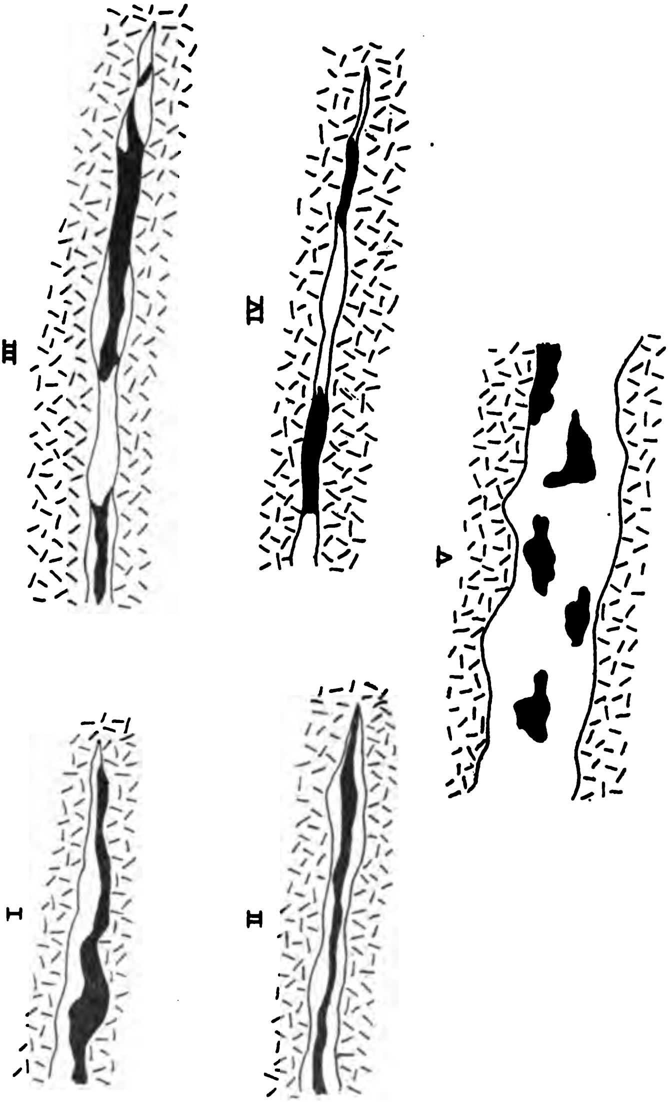


Fig. 12.—Calcite-Dolomite-Sphalerite Filling in Fractures of the Shenandoah Limestone. Shows Relations of Calcite-Dolomite to Sphalerite in Filling of Fractures Over Virginia Zinc District. White is Calcite-Dolomite. Black is Sphalerite. Dash Areas are Limestone. Natural Size.

in sufficient quantity to have precipitated the lead salts as sulphide, had the conditions been favorable to the subsequent downward circulating waters. (3) The conditions favorable to the conversion of sulphates into the carbonates and silicates of zinc, formed from the oxidation of the original sulphide. This follows, in part at least, from the statement made in (1); and, as stated elsewhere, the concentration of the oxidized zinc-ores near and along the irregular weathered surface of the limestone in the bottom portions of the residual clays.

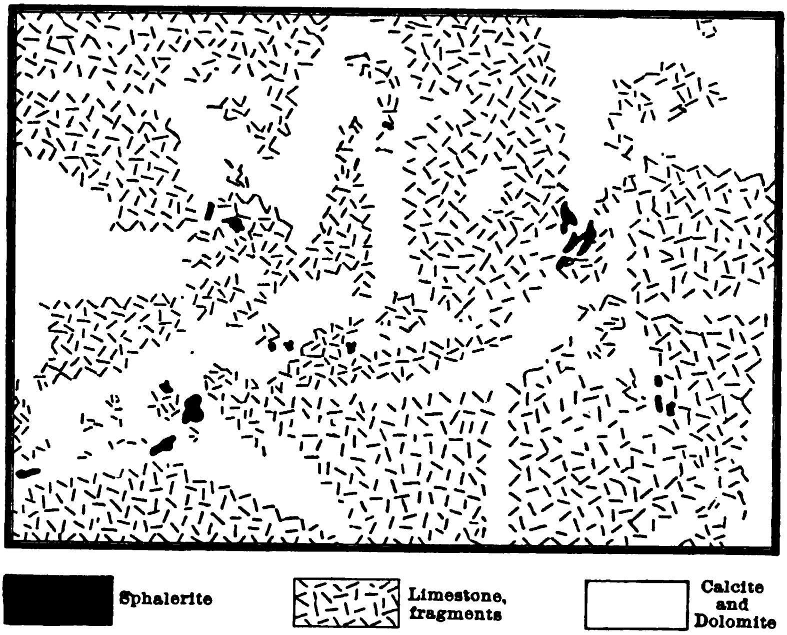


FIG. 13.—BRECCIATED LIMESTONE CEMENTED WITH CALCITE AND DOLOMITE. INGALLS MINES, NEAR NEW MARKET, TENN.

X. RELATION OF THE ORES TO GEOLOGIC STRUCTURE.

As already pointed out, the lead- and zinc-district of the Great Valley region of Virginia-Tennessee is one of intense deformation—folding, faulting and brecciation. Moreover, the localization and concentration of the ores follow closely these structural lines. Mineralization has not taken place through all parts of the breccia-zones, which follow the faulted anticlines; but only along some of the zones, in places and at irregular intervals, have the ores accumulated. Wherever the ores have been found they have been noted in some part of an anticlinal fold in or near a faulted breccia zone. The ores are, accordingly, of the breccia-type, as is shown in Figs. 13, 14, 15, 16, 17 and 18. At Austinville, Va., and near Tazewell, Claiborne county, Tenn., the ores appear in well-defined ore-bodies, ore-shoots; and they have resulted largely from a replacement process, mostly where the joint- and bedding-planes of the limestone intersect, and on the limb of a faulted anticline.

At the Austinville mines, in the extreme southern part of Wythe county, mining-operations have extended to some depth below local ground-water level into the unaltered sulphide ores, sphalerite and galenite. New river cuts across an anticlinal of the Shenandoah limestone near the mines. The accumulation of the ores is in the magnesian limestone strata, which dip about 45° SE., and form the corresponding limb of a faulted anticline. About 8.5 miles east of these mines, on the same (south) side of New river, and about a mile therefrom, are located the Bertha zinc-mines. Here, operations were entirely limited to surface mining of oxidized ores over a belt

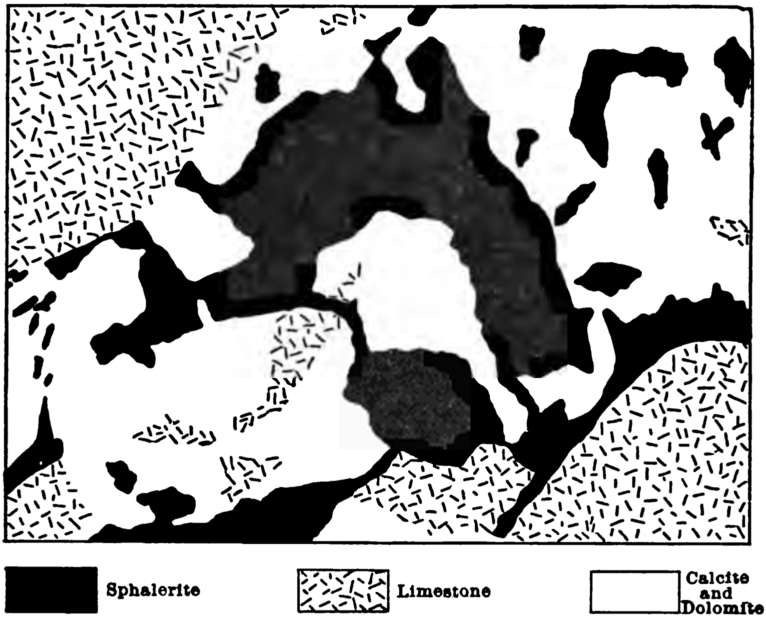


FIG. 14.—BRECCIATED LIMESTONE WITH BLENDE AND CALCITE. ROSEBERRY ZINC-MINES, MASCOT, TENN.

about 1,500 ft. wide, extending in the direction of the strike of the limestone, which is south 35° to 40° west. The dip of the limestone, where measured, was 25° NW., with flatter dips reported.

Recent prospecting at Cedar Springs, about 20 miles west of Austinville, in the extreme southwestern corner of Wythe county, Va., indicates that the ores occur on or near the faulted crest of an anticline. The distribution, therefore, of the ores in Wythe county is along a narrow belt which crosses the southern part of the county in a north of east direction. This belt is a structure zone—one of anticlinal folding and faulting—and the ores are deposited along and near the fault in the shattered and recemented limestone of the anticline.

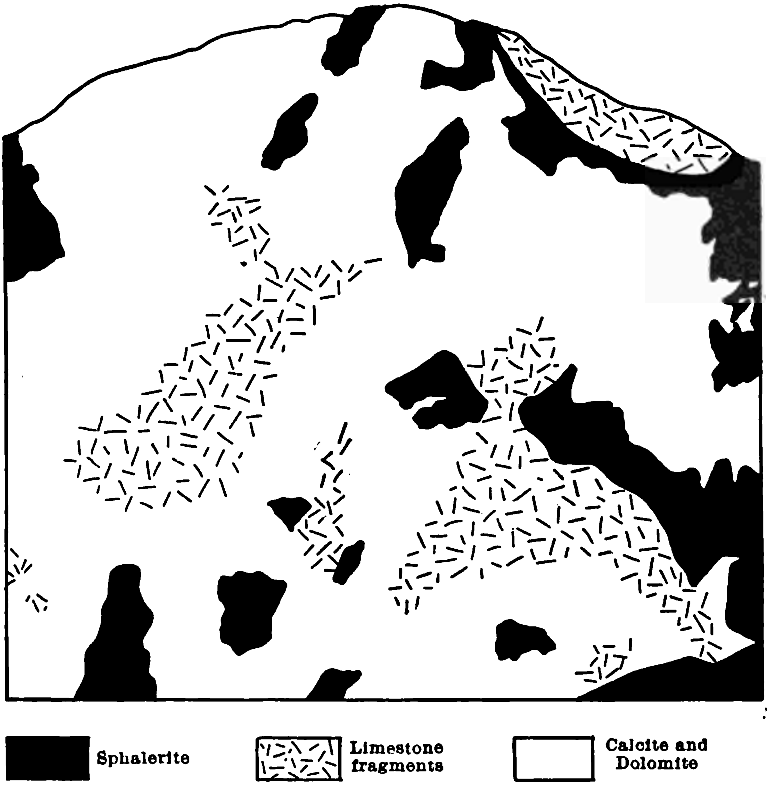


Fig. 15.—Brecciated Limestone Cemented with Calcite-Dolomite and Blende. Roseberry Zinc-Mines, Mascot, Tenn.

Precisely similar relations obtain in the Tennessee part of the district. At New Prospect, formerly known as Lead Mine

Bend, near Powell river, in Union county, Tenn., the ore-bearing area forms a narrow zone trending north 50° E., and lying just south of the crest of the Powell anticline, in which the rocks are crushed and broken.[3] Six miles southwest of Tazewell, in Claiborne county, Tenn., the ore-bodies occur in the lower part of the Knox dolomite, in an area of tilted rocks and near a fault.

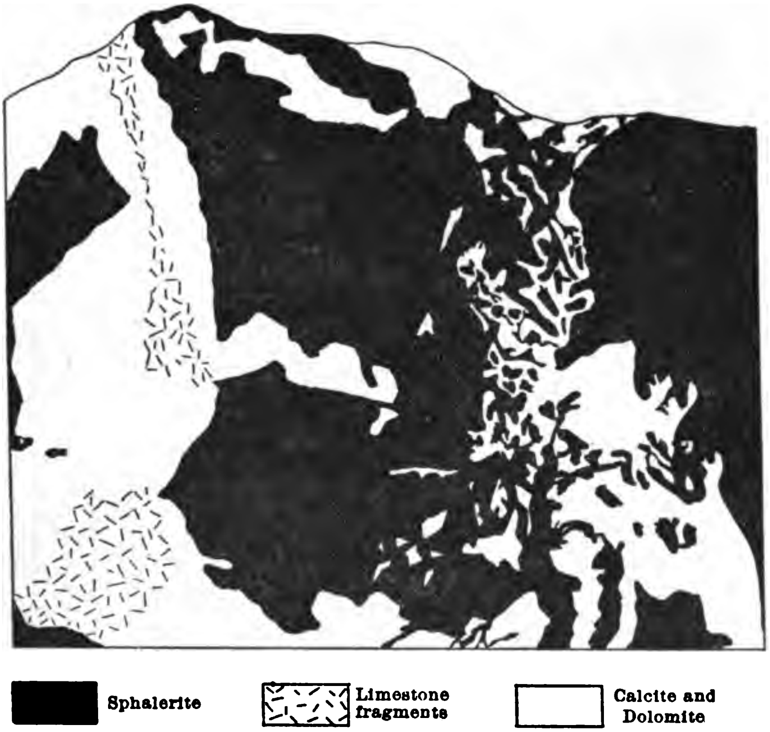


FIG. 16.—BRECCIATED LIMESTONE CEMENTED WITH CALCITE AND BLENDE. MOSSY CREEK ZINC-MINES, JEFFERSON CITY, TENN.

The group of deposits which extend southwestward from near New Market to near Knoxville are apparently located on the same zone of disturbance, several of which are definitely located in broken strata along small anticlines. The Mossy Creek deposit at Jefferson City, in Jefferson county, probably the most extensively mined zinc-ores in the district, occurs in a breccia zone; the ore filling the crevices in the mass and replacing some of the dolomite. According to Keith,[3] this breccia zone has nearly a north-south direction, and marks the plane of a large fault.

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[3] Keith, Arthur, *Geologic Atlas of the United States, Maynardsville Folio, Tennessee, U. S. Geological Survey*, p. 6 (1901).

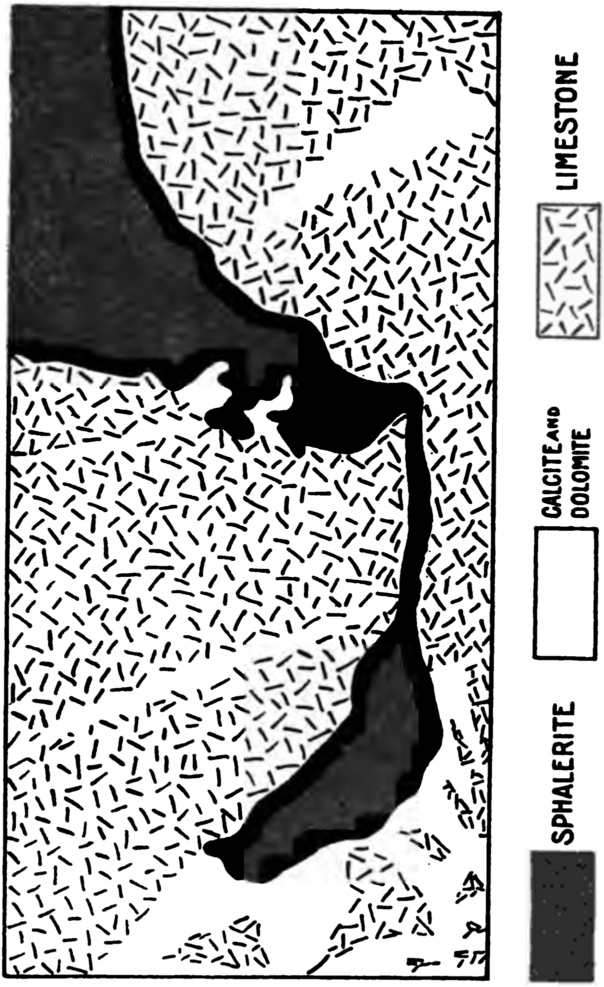

Fig. 17.—Breccia from the Cedar Springs Zinc Mining and Developing Company's Openings, Showing Angular Fragments of Limestone Cemented with Sphalerite, Calcite and Dolomite. Natural Size. Cedar Springs, Wythe County, Va.

XI. Petrography.

The Austinville mines in Virginia are taken as the type-locality of the replacement deposits. The description which here follows is that based on a study of thin sections of the rocks and ores from the above locality.

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[3] Keith, Arthur, *Geologic Atlas of the United States, Morristown Folio, Tennessee, U. S. Geological Survey* (1896).

In thin sections, under the microscope, the rock is evenly granular and wholly crystalline, with no admixture of other mineral than dolomite and the ores. The dolomite exhibits both the characteristic cleavage and the twinning, as shown in Figs. 7 and 8. The crystalline grains are filled with minute inclusions, usually of an indeterminable nature. Some of these are of a dark brown and a reddish brown color, and are certainly iron oxide. Frequently these have accumulated along the sutures between the grains, and extend outward into the substance of the grains, rendering those parts opaque and nearly black to polarized light. Parts of some sections show an opaque yellowish color, due to discoloration from iron oxide staining. In some sections the iron oxide fills the irregular

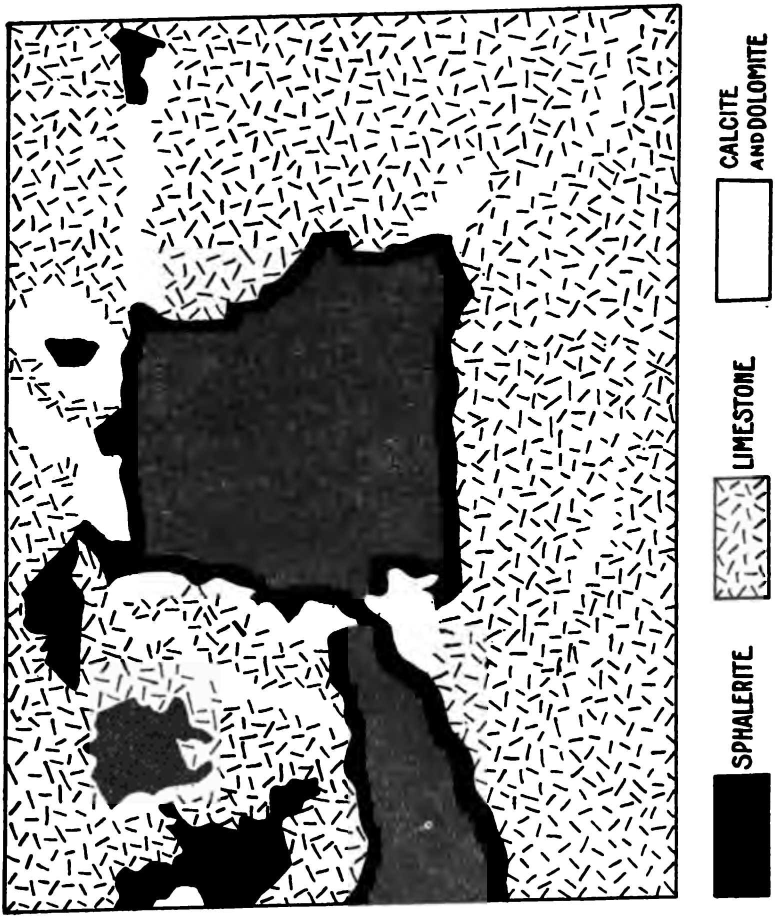

FIG. 18.—BRECCIA FROM CEDAR SPRINGS, WYTHE COUNTY, SHOWING RELATIONS OF SPHALERITE TO CALCITE-DOLOMITE FILLING AND TO THE LIMESTONE. SOME REPLACEMENT OF THE LIMESTONE BY SPHALERITE IS CLEARLY SHOWN. Natural Size.

thread-like cracks, and has been derived from pyrite by oxidation.

Areas of fresh pyrite are distributed through some of the sections, which show characteristic replacement-borders. The peripheries of the pyrite areas are characterized by re-entrant angles, which correspond to the cleavage angles in the dolomite grains. In some instances a partial cavity is left filled with dark amorphous matter resembling iron oxide—suggesting oxidation of the original pyrite. Galenite shows equally well the evidence of formation by replacement of the dolomite substance along the cleavage directions. The border portions of the large irregular areas show perfectly straight and sharply-defined edges bounding re-entrant angles, which correspond to the cleavage angles of the dolomite grains. From the margins are given off irregular, long thread-like stringers, which ramify outward into the dolomite substance in spider-like fashion. Some of these fill, in part, the sutures between the dolomite grains, rimming the grains for considerable distances; others fill irregular microscopic fractures in the dolomite grains. This phenomena is typically shown in Figs. 7 and 8.

XII. WEATHERING.

The Austinville mines in Virginia are again taken as the type-locality because of the extensive mining operations which expose excellent sections of the fresh limestone and its residual decay for study.

The fresh rock is a recrystallized magnesian limestone. The first and early stage of weathering is a physical crumbling of the crystalline rock into a dolomitic sand, varying from light to brown red in color, in which only slight oxidation is shown. When stripped of its residual decay, the limestone presents an exceedingly irregular pinnacled or "chimneyed" surface, as shown in Fig. 19. The limestone "chimneys" are buried to a variable depth by the decay, with the decay covering the inter-areas, reaching in extreme cases, a depth of nearly 100 ft. The general character of the clays forming the residual covering is red in color and highly ferruginous in composition.

A characteristic feature of the weathered surface of the uncovered limestone "chimneys" is a pronounced irregular pitted aspect, shown in Fig. 20. A close examination of the lime-

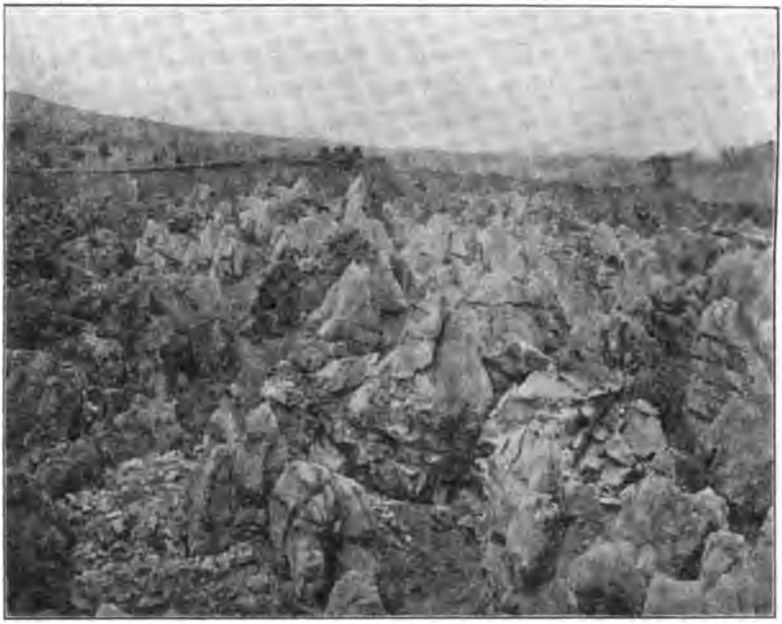

Fig. 19.—View in Open Cut of the New River Mineral Company's Mines at Ivanhoe, Va., Showing the Typical Pinnacled or "Chimneyed" Surface of Limestone Resulting from Weathering. (H. Ries, photo.)

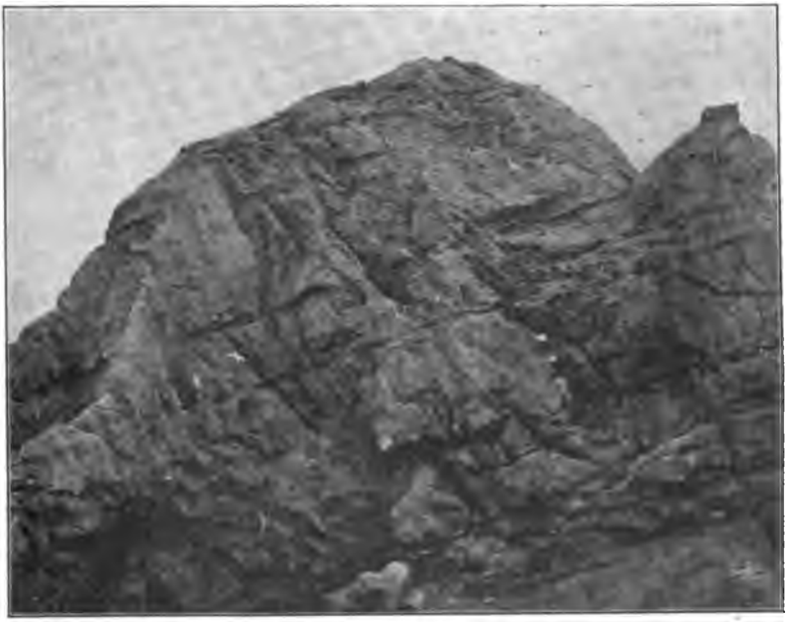

Fig. 20.—Near View of a Part of One of the Limestone "Chimneys," Showing the Pitted and Etched Surface from Weathering Along the Bedding and Invisible Fractures. (H. Ries, photo.)

stone surface shows this peculiar form of weathering to be due to solution and etching along the irregular fracture-lines in the rock. The weathering of the limestone surface into the characteristic pinnacled or "chimneyed" surface is controlled largely by the jointing of the rock. This form of weathering is characteristic of the openings at Bertha, Austinville and Ivanhoe, Va., and in some of the openings made for mining brown iron-ore. The location of each of these is along the zone of folded and crushed recrystallized limestone. Fig. 21 is a view showing the limestone weathering in one of the mine openings at Austinville, Wythe county, Va., and Fig. 22 is a view of similar limestone weathering at the Bertha mine, Wythe county, Va.

The following analyses of the fresh and partially decayed limestone and the residual clay will serve to indicate the changes involved in the transformation of the fresh limestone to the stage of decay represented in the residual clay:—

	I.	II.		III.
	Per Cent.	Per Cent.		Per Cent.
Lime,	29.77	29.86		0.24
Magnesia,	20.69	20.68		1.02
Alumina,	0.22	0.94		26.27
Ferric oxide,	0.19	0.38		10.53
Manganese oxide,	0.19	0.20		none
Zinc oxide,	none	0.46		none
Soda,	0.50	0.18		undet.
Potash,	0.30	0.05		undet.
Carbon dioxide,	44.43	42.55	(H_2O 110° C. +)	2.06
Water,	3.41	4.06	(H_2O 110° C. —)	7.41
Insoluble matter,	0.42	0.80	(SiO_2)	48.96
Total,	101.12	100.16		96.49

I. Average of three analyses of the fresh crystallized magnesian limestone, Austinville, Va., Dr. W. E. Barlow, analyst.

II. Average of three analyses of dolomitic sand derived from the crystallized magnesian limestone, Austinville, Va., J. R. Eoff, Jr., analyst.

III. Analysis of deep red residual clay derived from the crystallized magnesian limestone in the open pits of the Austinville mines, Va., J. R. Eoff, Jr., analyst.

On comparing these analyses, essentially no difference is shown in the principal constituents of specimens I. and II., which clearly indicates that the early stage in the weathering of this limestone is purely a physical one, and is unaccompanied by any appreciable chemical action. In the next or final stage

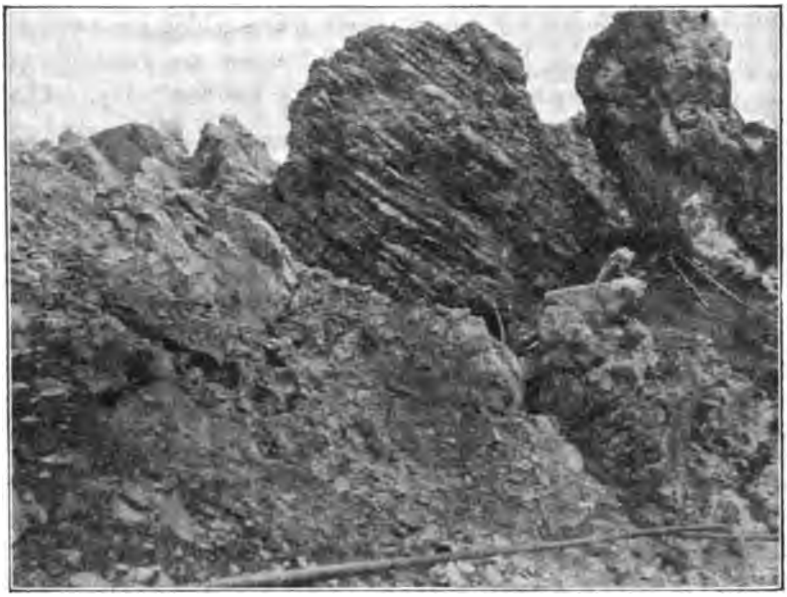

FIG. 21.—VIEW SHOWING LIMESTONE WEATHERING IN ONE OF THE MINE OPENINGS AT AUSTINVILLE, WYTHE COUNTY, VA.

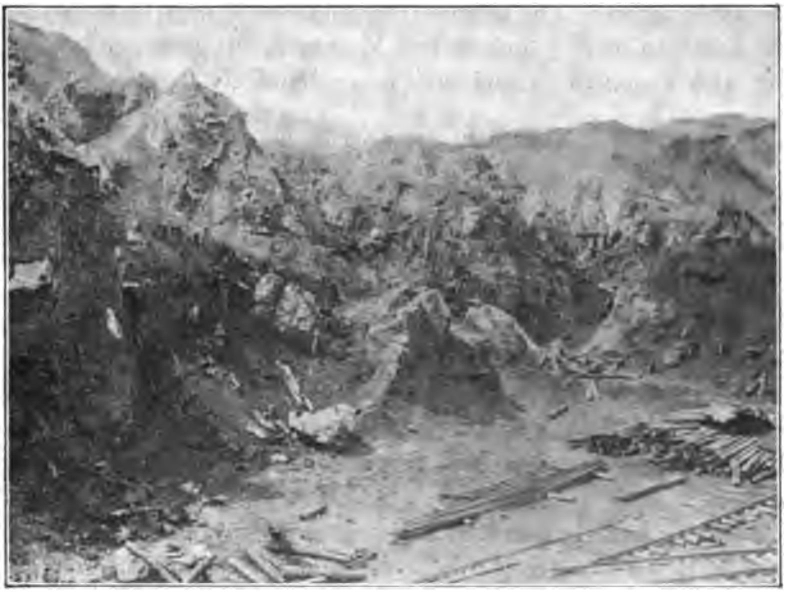

FIG. 22.—VIEW SHOWING LIMESTONE WEATHERING IN ONE OF THE MINE OPENINGS AT BERTHA, WYTHE COUNTY, VA.

of the decay, shown in specimen III., the results are markedly different; the more refractory constituents, which are present in the fresh rock in barely more than traces, are retained as the principal ingredients composing the residual clay. The carbonates of lime and magnesia, which practically make up the fresh rock, have suffered most from solution and removal, and are only present in the residual clay in very small amounts.

XIII. Age.

Since the ores have been shown to follow rather closely the faulted breccia-zones, they were formed after the period of deformation which resulted in the folding, faulting and shattering of the limestone near and along the lines of breakage. This period of deformation probably dates back to late in, or after the close of, the Carboniferous. The original sulphide ores must antedate the secondary ores, since the latter were derived from the former by the usual processes of atmospheric decay. The altered or secondary ores originated with the periods of peneplanation of which there were several, the earliest and most extensive one being of Cretaceous age, followed by later and less extensive ones cut during Eocene and Neocene times. The original sulphide ores may be as old as the Permian or as young as late Mesozoic, but evidence is lacking with which to fix their age more definitely.

XIV. Origin of the Ores.

The statements here made concerning the genesis of the zinc- and lead-ores apply only to the Great Valley region of Virginia-Tennessee, and do not to the single deposit east of the Blue Ridge, in Albemarle county, Va. The conditions, here, are totally unlike those of the Great Valley region. In the Albemarle county area the ores occur in crystalline schists, and their genetic relation to igneous masses is fairly well established, while the deposits of the Great Valley region are as definitely shown not to have any relation whatever to igneous rocks.

So far as known, there are no igneous intrusions found within the limits of the Great Valley region of Virginia-Tennessee with which to connect the ores. While it is true the ores are related to the folding and faulting of the region, there appears no good reason for regarding the ores as having been derived from profound depths within the interior of the earth, and later introduced into the limestone from solutions. Indeed, the evidence is against this source of the material, for, when ore-deposits have been formed by such a process, they are usually associated with a characteristic set of minerals, such as compounds of arsenic, antimony and silver, and frequently by fluorspar, etc., all of which, with the exception of barely more than a trace of fluorspar, are entirely absent.

The Cambro-Ordovician limestone is the only formation in the district that is positively known at present to contain lead- and zinc-ores. Other limestones have good development over parts of the district, and apparently offered equally as good advantages for ore-deposition as the Cambro-Ordovician. There appears no real reason why the lead- and zinc-deposits should have been deposited in one formation and not in another, except that the source of the material was limited to the single formation in which they have been concentrated and localized, and in which they are now found. It further seems unnecessary to appeal to highly-heated waters either from profound depths or from connection with igneous intrusions as a source of the material, since, as already stated, the field-evidence is against such a process. This evidence favors the original deposition of the ores in the Cambro-Ordovician limestone in disseminated form, but so very sparsely disseminated as to render subsequent localization and concentration of them by underground waters along certain structural lines, previously indicated, in their present workable form. It has been pointed out that in some of the Virginia deposits the ores are intimately associated with the more carbonaceous layers of the limestone. Similar associations of the ores with limestone containing organic matter have been indicated for other deposits in Virginia and Tennessee. These associations indicate that the ores were probably introduced as sulphates, and were reduced by the organic matter in the limestone and deposited as sulphides.

In addition to the sulphate cycle, it seems probable that there was a second or sulphide cycle in which the metals were transported as soluble sulphides and were deposited as such. This was probably the process of deposition at Austinville, and in some other of the Virginia deposits.

Many of the typical breccia-deposits show only slight or little replacement of the substance of the limestone-fragments by the ores, but the ores were introduced and deposited with the calcite-dolomite filling, which cement the broken rock-fragments. Other deposits, like those at Austinville, Va., and Straight Creek, Tenn., take the form of definite ore-shoots, which have resulted largely by a replacement process, principally along the intersections of the joint- and bedding-planes. The mingling of the ore-bearing solutions with other solutions in the faulted breccia-zones, and the reaction of the ore-bearing solutions on the wall-rock, limestone, largely resulted in the precipitation of the ores, where not connected with reduction and precipitation by organic matter.

As has already been pointed out, the ore-deposits are associated with the folding and faulting of the limestone, following rather closely the brecciation of the rock produced by this deformation. This produced ready channel-ways in the limestone for the free circulation of the underground water, and it was along these directions that the conditions were favorable to the precipitation and deposition of the metallic sulphides.

XV. THE VIRGINIA DEPOSITS.

With one exception, the workable deposits of zinc- and lead-ores are confined to the Valley region of southwestern Virginia, which I have already described in much detail in my report on the lead- and zinc-deposits of Virginia,[4] hence they need not be repeated here, particularly since they are closely similar to the Tennessee deposits, which form a part of the same area and are described below.

The single deposit of lead- and zinc-ores in Albemarle county, Va., does merit description here, since it marks the only type of its kind in these metals known in the entire south. The mine owned by the Albemarle Zinc and Lead Co. is located 2 miles slightly north of east from Faber, a station on the Southern railway, just across the Nelson county line in Albemarle county, in the foot-hills of the Blue Ridge, and therefore in the crystalline schists of the Piedmont plateau. (Fig. 28.) The main developments comprise three shafts, sunk respectively to depths of 25, 50 and 120 ft., and separated by a distance of about 1,000 ft. between the two extreme shafts. In addition to the three shafts an adit-level was run into the hill from the valley bottom, and a cross-cut run from the adit, in and along the vein, for a distance of 140 ft., which extends beyond the middle and deep shaft. The map, Fig. 24, gives a plan of the mine and the plant.

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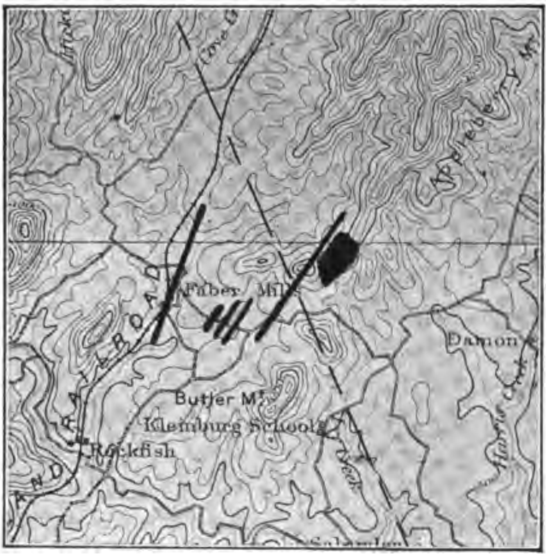
[4] *Bulletin No.* 1 *of the Virginia Geological Survey* (1905).

The rocks in which the lead- and zinc-ores occur are metamorphosed crystalline schists, cut by a series of basic igneous dikes of diabase and diorite. Microscopic study indicates several types of the schists which, in the outcrop, are easy of differentiation. These are thinly schistose, sericitic and chloritic schists, alternated or interbedded with a quartz-mica conglomerate schist. The sericite schist is quite garnetiferous, being filled in places with small, perfect crystals of red garnet. The chlorite schist is the ore-bearing rock. It is thinly fissile, and thoroughly crinkled, the axes of the crinkling making an angle of about 90° with the planes of fissility. The rock contains little or no quartz and feldspar, but is largely composed of ferromagnesian silicates. By the addition of quartz this grades



Scale, ½ inch = 1 mile. Contour Interval, 100 feet.

FIG. 23.—MAP OF LEAD- AND ZINC-DEPOSITS IN ALBEMARLE COUNTY, VA. BUCKINGHAM SHEET, U. S. G. S. Geology by Thomas L. Watson.

into the conglomerate schist, which is composed of quartz, a little feldspar, and some mica, more or less altered to chlorite. The rock contains small fragments of granite, gneiss and schist, which are oriented in the direction of the schistosity, and are partly crushed and mashed from the effects of pressure.

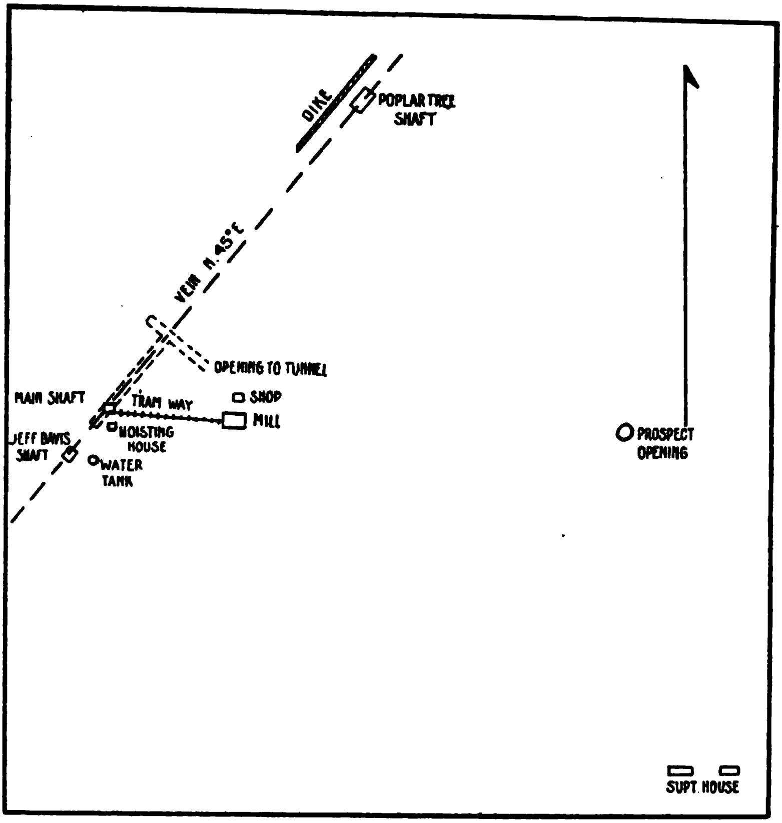


FIG. 24.—PLAN OF ALBEMARLE ZINC AND LEAD COMPANY'S MINE, NEAR FABER, ALBEMARLE COUNTY, VA.

The fragments are both angular and rounded. The rock is also cut in places by thin stringers of quartz and pegmatite.

The study of this series of rocks, both in the field and in the laboratory, leaves no doubt of its sedimentary origin. The strike is N. 45° to 50° E. and the dip is 70° to 85° NW. The exact age of these rocks is yet unknown, but they can probably be referred to pre-Cambrian.

At Faber's station, on the east side of the Southern railway, the schists are cut by a large diabase dike, which is traceable for several miles in a N. from 5° to 10° E. direction. Under the microscope, thin sections of the rock from this dike show the typical diabase texture and normal composition. From this point eastward to the mine-openings numerous intrusions of diorite are noted. One of the largest of the diorite dikes is exposed within 25 paces of the Poplar Tree shaft. These dikes have a trend of N. 45° E., and are parallel to the trend of the metalliferous vein. The rock composing the dikes shows considerable alteration of the minerals composing it. Hornblende and its common alteration-products, with quartz and some feldspar, comprise the mineral constituents. The diabase dike at the station is of the normal Mesozoic type; its substance is entirely fresh and unaltered, and it is probably younger than the diorite intrusions.

The metalliferous vein is reported to have been traced for a distance of several miles. It varies in width, averaging about 4 ft.; the strike is N. 45° E., exactly paralleling the diorite dike 25 ft. distant on the northwestern side; and it dips 80° to 85° NW. Where opened, it is of the lenticular type, composed of bulbous bodies of fluorspar mixed with some quartz, through which the ore, blende and galena, are distributed. The fluorspar-quartz lenses vary much in size, and are often connected by a mere film of the same minerals, which at other times may be lacking altogether, thus giving the appearance of the vein in such cases of having given out. A marked banded structure is frequently indicated, particularly near the walls, which is due to included plates of the schist. These films or plates are often characterized by some impregnation of the ore. The relation of the fluorspar-quartz lenses to the enclosing schists are shown in Fig. 25.

The ore, consisting of blende and galena, occurs principally in the fluorspar-quartz lenses, although the schists next to the lenses is often more or less mineralized. The blende and galena may occur in separate bands and irregular masses distributed through the lenses; or they may occur intimately admixed in a single band or mass in the same lens. Fig. 26, which is a drawing of a large mass broken from one of the lenses, shows the typical occurrence. On working-out the ore, the two walls are entirely smooth and solid. Enough work has probably not yet been done to indicate the true relations of the ores, blende and galena; but, so far as developments extend, there seems to be some tendency in the galena to follow or occur close to the foot-wall and the blende the hanging-wall. This relation may not continue on depth. It is the belief of the miners that the fluorspar and blende increase on depth, and that the quartz and galena decrease. Sufficient depth has not been reached, nor enough underground work done, to establish any relations of the ores to each other and to the gangue.

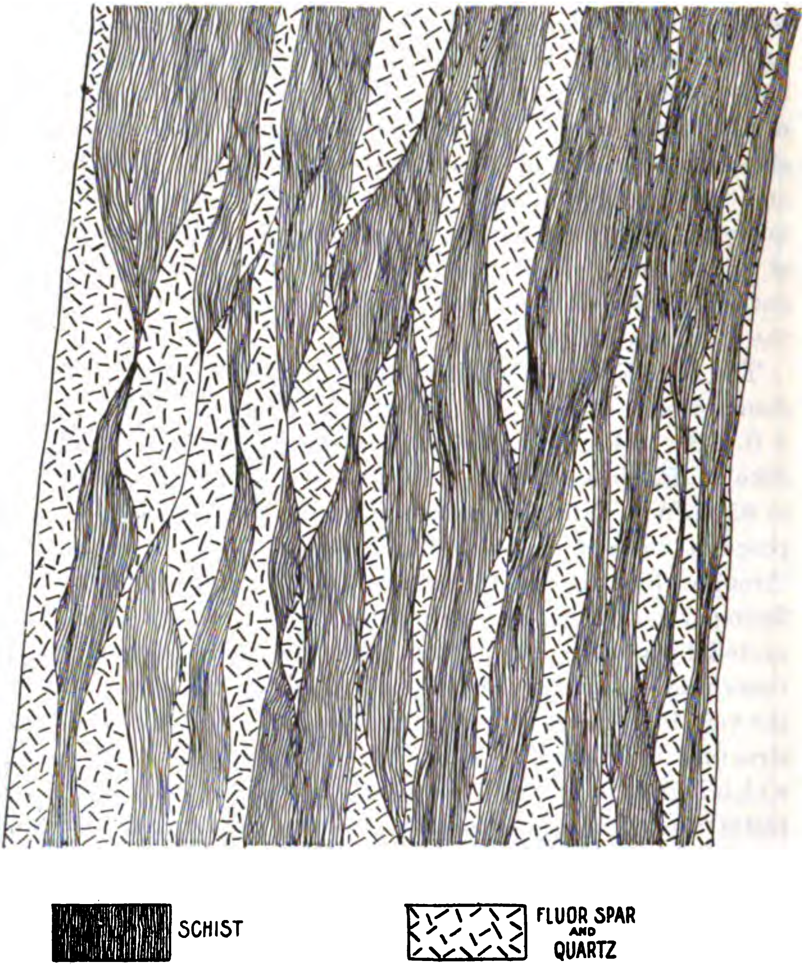


Fig. 25.—Diagram Illustrating the Type of Fissure-Vein Formed at the Albemarle Zinc- and Lead-Mine, Albemarle County, Va.

In addition to the principal ores, blende and galena, some chalcopyrite occurs and some smithsonite. Cerussite and azurite were reported some years ago from the dumps. The galena is argentiferous, and arsenic and antimony are reported in very small quantities. Fluorspar is the principal gangue mineral, with more or less quartz, and a little calcite and feldspar have been reported. The fluorspar is mostly white, but quite a sprinkling of the violet shade occurs in places.

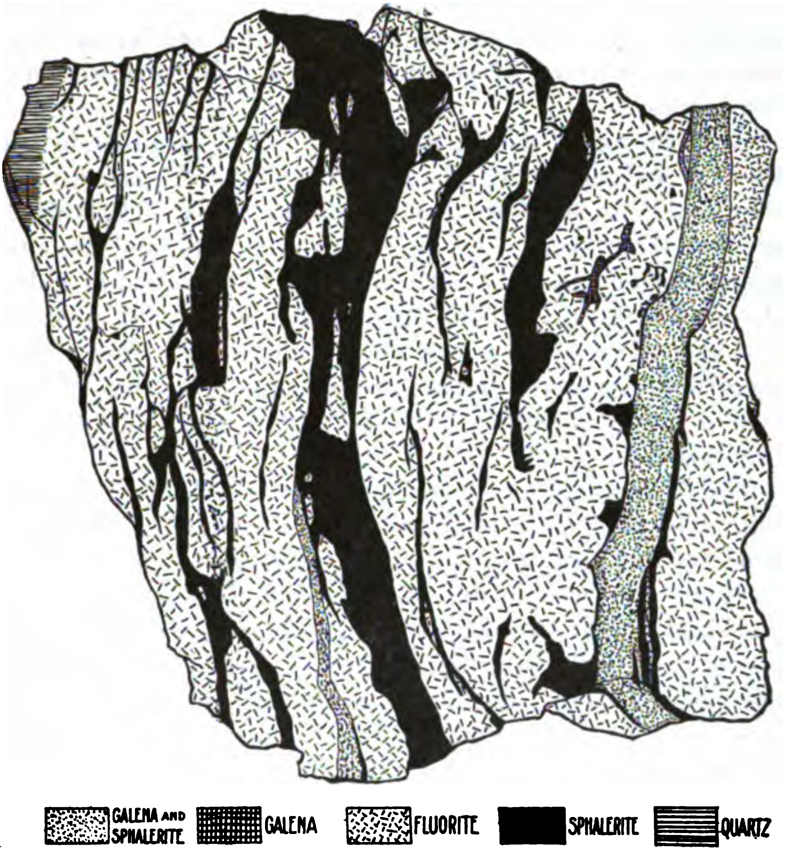


Fig. 26.—Specimen of Fluorspar Lens, Showing Distribution of the Sulphide Minerals, Sphalerite and Galenite. Albemarle Zinc and Lead Company's Mine, Near Faber. About ⅓ Natural Size.

The very close association of the vein with dikes of igneous rocks makes it reasonably certain that the ores are genetically related to the igneous intrusions. The evidence of such relationship is strengthened when the composition of the gangue and the metals is considered. The principal and abundant gangue mineral, fluorite, and the metallic sulphide, argentiferous galena, with traces of arsenic and antimony, constitute an association of minerals such as can best be explained on the supposition of highly-heated conditions. Such could have been deposited only from waters of deep-seated origin, or from waters whose source of heat was derived from intruded igneous masses.

As to the age of the deposits, it can only be said that, in case the ores are genetically related to the dikes of igneous rock, they could not be older than the diorite dikes. These dikes are found, however, to be altered in every case, and are presumably older than the dike of diabase found east of Faber station, which can, without much doubt, be assigned to Mesozoic age. The deposits, therefore, could not be younger than the diabase intrusion, and are probably not older than the period of dioritic intrusion, the exact age of which has not yet been fixed.

The dry process for separating the ore is employed in milling. The problem is principally one of separating the blende from the fluorspar, and of freeing the zinc-concentrates from lead, and the lead-concentrates from zinc. The ore is crushed and sized to pass a 16-mesh screen. All ore above this size is passed back to the rolls and crushed until properly sized. The ore thence goes to 4 rough jigs, and from here to 4 finishing-jigs. It is claimed that the tailings are practically freed from all ore by this process. If not, the jigs can be so regulated as to make a nearly complete separation. The important factor is that of the time involved in regulating and running the jigs. The trials so far made at the mill required the jigging-process to be repeated several times on the same ore before a clean concentrate was obtained.

Through the kindness of Mr. Wikins U. Greene, Mining Engineer in charge of the plant, several bags of the lead- and zinc-concentrates were sent to me and were separately analyzed, giving the following results:

	Lead-Concentrates. Per Cent.	Zinc-Concentrates. Per Cent.
Lead,	63.05	6.02
Zinc,	12.12	47.88
Iron,	3.16	7.26
Copper,	trace	0.94
Sulphur,	19.32	29.52
Calcium fluoride,	1.31	4.74
Insoluble residue,	1.08	2.90
Total,	100.04	99.26

It is claimed from the tests made on the concentrates from this mill, that the following results represent fairly well the average composition:

Zinc concentrates: Zinc, 55 per cent.; lead, 4 per cent.
Lead concentrates: Lead, 85 per cent.; zinc, 4 per cent.
Copper about 0.05 per cent.
Iron about 3 per cent.

The dry process, employed at this plant for separating the ore, differs essentially from the wet process, in the form of jig used. The Krom jig is used, made of screens of different size meshes, substituting air for water. These can be set to 700 puffs of air per minute.

XVI. THE TENNESSEE DEPOSITS.[5]

1. *Introductory Statement.*

The principal lead- and zinc-deposits of Tennessee are grouped in two distinct belts; one lying near Powell river and the other near the Holston river. In the former, or Powell belt, ores of both lead and zinc occur, intimately associated, but varying widely in relative proportions. In the Holston belt lead-ores occur but sparingly.

While ores of the two metals have been found in nearly every county of the upper East Tennessee region, only a few of them had proved, until very recently, to be of economic importance. Mining in the past was confined largely to Mossy Creek, New Market, Straight Creek and Lead Mine Bend. Within the last 12 or 18 months active operations in deep mining have been in progress, confined chiefly to three distinct areas, namely, the Lead Mine Bend area in Union county; the Straight Creek area in Claiborne county; and the Holston River area in Knox and Jefferson counties. The greatest development work has been in the Holston River area, which extends from 4 miles east of Knoxville for more than 20 miles northeastward, paralleling the Holston river and the Southern railway. Extensive drilling over most of the area has been in progress during the past 12 or 18 months. On the property of the Roseberry Zinc Co. drilling has exposed ore at a depth of 158 ft., and it extends to the extreme depth drilled, 202 ft. The ore is reported to average from 12 to 15 per cent. of metallic zinc, and it produces a concentrate containing more than 60 per cent. of zinc.[6]

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[5] The Virginia deposits are described in considerable detail by me in *Bulletin No. 1 of the Virginia Survey*, hence they will not be repeated here.

2. *Description of the Mines.*

The most important mines in the East Tennessee region are here divided and discussed under three separate areas, namely, (1) the Lead Mine Bend area in Union county; (2) the Straight Creek area in Claiborne county; and (3) the Holston River area in Knox and Jefferson counties.

(a) *The Lead Mine Bend Area, Union County.*[7]—This area lies along and near Powell river, about 16 miles west of the Straight Creek mine, in Claiborne county. It has been extensively developed, and, as the name implies, it was originally worked for lead. Active prospecting is now in progress over the area. The ore-bearing area is a narrow zone, having a direction of N. 50° E., in which the rocks are crushed and broken; and it lies just south of the crest of the Powell anticline. At New Prospect the lead-ore is prominent, and the mineralized zone is traced for several miles northeast on both sides of the river. Lead- and zinc-ores are found here and there for a distance of 9 miles S. 70° W. of New Prospect.

The ore consists principally of galena and blende, with smithsonite, calamine, cerussite, and a very little pyrite, with calcite. It occurs in the lower layers of the Knox dolomite.

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[6] *Engineering and Mining Journal*, vol. lxxx., No. 7, p. 311 (August 19, 1905).

[7] I did not visit this area; the information on it has been compiled from various sources, principally from the *Geologic Atlas of the United States, Maynardsville Folio, Tennessee, U. S. Geological Survey*, by Arthur Keith; and *Production and Properties of Zinc*, by W. R. Ingalls.

Smithsonite, calamine and cerussite occur near the surface in the limestone decay, and have been derived by weathering from the blende and galena. Wide variation is shown in the relative proportions of blende and galena. At New Prospect, galena is the dominant ore, while, in other places in the area, blende forms the principal ore.

The ores are described as occurring in the crushed limestone, and in crevices which break the anticlinal fold longitudinally. The limestone is also mineralized for some distance on each side of the crevices.

Lack of transportation-facilities seems to have been the principal hindrance to the development of this area. The ore from the lead-mines was carted for a distance of 20 miles over a rough road, or else it was floated down the Powell and Clinch rivers on flat-boats to Clinton, where it was smelted.

(b) *The Straight Creek Area, Claiborne County.*—The principal mine in the Straight Creek area is located on Straight creek, about 5 miles SW. of New Tazewell, and about 3 miles west of Lone Mountain station, on the Knoxville and Cumberland (Southern) railway. It is reported to have been opened first about 25 years ago, and it has been worked since at intervals by several different companies. It is worked at present by the Tennessee Zinc Co. of Cincinnati, O.

The ores occur in the lower layers of the Knox dolomite, which, at this place, is a fine-grained and compact limestone, usually of dark color, and containing much organic matter in places. The beds strike N. 70° E. and dip from 35° to 45° SE., which increases to 60° in going eastward. The ore-bodies are located near a fault, and the rock is crushed and broken in places, forming a breccia in which the spaces between the fractures are smaller than in other places. The filling is largely composed of ore, with but little calcite and dolomite. Subsequent movement is indicated in numerous slickenside surfaces, coated with carbonaceous matter of some thickness, and at times with a thin film of pyrite.

The old workings comprise several pits, from 40 to 60 ft. deep, opened along the strike of the rock on top of the limestone ridge, and several hundred feet above the valley bottom. The ore mined comprised only the silicate and carbonate of zinc. Considerable lump iron-ore (limonite) is shown in the dumps. Joints, approximately normal to the bedding-planes, are conspicuously developed in the limestone of the old openings. The ore is reported to have been traced along a NE–SW. direction for a distance of about 4 miles, and recent prospect-openings that promise well have been made on Birch creek, about 2 miles west of the present mines.

Recent work at the mines comprises a single tunnel driven into the ridge from near the valley bottom in a northerly direction for a distance of about 700 ft., and at a depth of about 150 ft. below the surface. Stoping at this point developed an ore-body about 40 by 60 ft. in the direction of the strike, and at right angles to the axis of the tunnel. The dip of the ore-body (ore-shoot) is toward the east, and it pinches in the same direction. So far as developments extend at this locality, the ore-bodies in general indicate both eastward dip and pinching; and they divide or split at the west end.

In the early mining much soft ore, mostly silicate, was removed; but within recent years mining has been confined to the sulphide ores. Blende, some galena, and in places much pyrite, make up the sulphide ores. These are intimately associated, and contemporaneous deposition is indicated. In places alternating bands of the sulphide ores were observed. Usually the pyrite and galena are more or less distributed through, or enclosed by, the blende, though each may occur separately, as is often the case. The blende is fine granular, gray in color, and is disseminated. Pyrite may occur in masses measuring as much as a foot or more in diameter; or as stringers, filling the fractures and cementing the broken rock-fragments forming breccia; or in association with the blende and galena.

Very small stringers or veinlets of blende, less than an inch in width, may fill the rock-fractures or cracks, gradually becoming larger and larger until the rock substance is very largely or entirely replaced by the ore. This replacement process is illustrated in Figs. 27 and 28. A very striking feature at these mines is the extensive scale on which replacement of the rock substance by the sulphide ores has taken place. Very little white calcite or dolomite occurs, though this may be due, in part at least, to the calcite or dolomite being impure and discolored by iron or other impurities, as is undoubtedly true in places. The small amount of white calcite or dolomite observed was present in the form of the thinnest films, cementing the broken rock-fragments together. Barite, fluorite and quartz do not occur. Fig. 29 illustrates the replacement breccia ore, showing limestone with blende and galena.

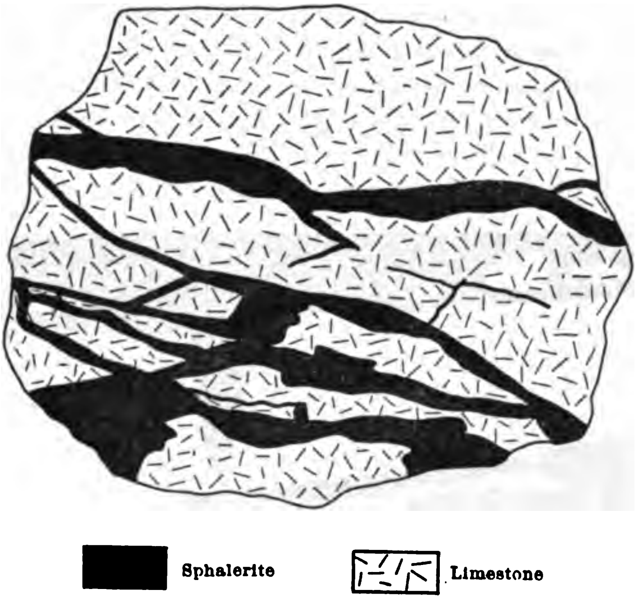

FIG. 27.—ORE SHOWING REPLACEMENT OF LIMESTONE BY BLENDE. STRAIGHT CREEK ZINC-MINE, CLAIBORNE COUNTY, TENN.

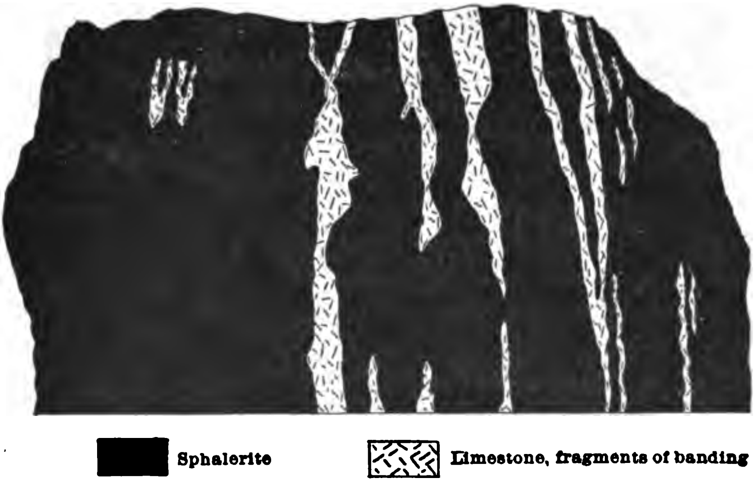

FIG. 28.—ORE FROM THE STRAIGHT CREEK MINES, SHOWING REPLACEMENT OF LIMESTONE ALONG BANDING BY SPHALERITE. CLAIBORNE COUNTY, TENN.

As is stated above, the rock in the mine-openings bears striking evidence of its being more highly carbonaceous than elsewhere,—a fact which probably indicates that the solutions contained the metals as sulphates; that they were introduced as such, and were reduced and precipitated as sulphides. Filling by the ores was first along the fracture- and bedding- planes extending gradually out and into the rock substance on each side by a process of replacement. Considerable oxidation is manifested to the entire depth of stoping, 150 ft., in large clay-seams, which fill the fractures, and some associated secondary soft ores.

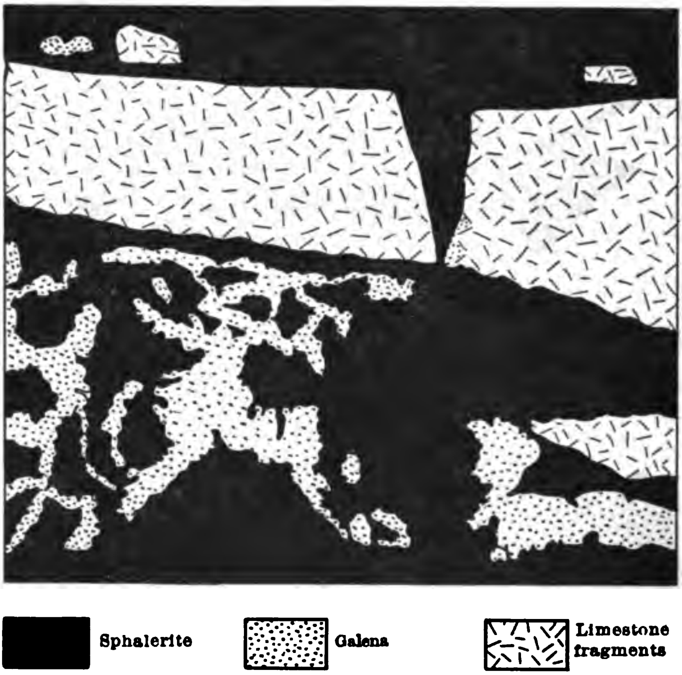

Fig. 29.—Replacement Breccia Ore, Showing Limestone with Blende and Galena. Straight Creek Mines, 5 Miles Southwest of New Tazewell, Claiborne County, Tenn.

A mill, fitted with crusher, rolls and hand-jigs, was formerly operated at the mines, but at the time of my visit, in April, 1905, preparations were being made to install a commodious and modern mill. The ore as mined is cobbed to a yield of about 45 per cent. of zinc; and it will probably concentrate in milling to an average of not less than 52 per cent. of zinc. The amount of iron present will, as a rule, probably not cause much trouble, and, by fine crushing and jigging, much of the lime can be eliminated. Probably the chief trouble is the question of transportation. Carting over a rough road for a distance of 6 miles is necessary at present. The nearest railroad point can be reached at a distance of about 4.5 miles.

Very recently prospecting near Goin Post Office, on Sugar and Slate creeks, in Claiborne county, and from 6 to 7 miles west of Tazewell, has exposed deposits of intimately associated blende and galena.

Occurrence of the Straight Creek Ore, Tenn., Compared with that at Austinville, Va.—So far as developments have been made in the Virginia-Tennessee district, only at the Straight Creek mine in Claiborne county, Tenn., and the Austinville mine in Wythe county, Va., have well-defined ore-bodies been noted. Over other parts of the district the ore is of the typical disseminated breccia type, in which replacement has played only a subordinate part.

The principal points of resemblance in the occurrence, association and genesis of the ore at these two mines are: (1) the presence of well-defined ore-shoots; (2) the intimate association of galena and blende with subordinate pyrite; (3) similarity in the process of formation in the ore-bodies to the extent of first forming along the intersection of the joint- and bedding-planes; (4) the extensive replacement of the limestone substance by the sulphide ores. At each one of these mines the process of ore-formation was largely one of replacement.

The essential points in which the two differ are: (1) the rock (limestone) in the Tennessee mine is not so metamorphosed (re-crystallized) as in the Virginia mine, and less secondary calcite and dolomite occurs in the former mine; (2) the presence of considerable organic matter in the limestone at the Straight Creek mine, and its essential absence at the Austinville mine; (3) the probable introduction of the metals in the form of the sulphates in the Tennessee mine; their reduction by the organic matter present in the limestone and deposition as the sulphides. It seems equally probable that at the Austinville mine the metals were introduced as soluble sulphides, and were deposited as such. In other words, these two mines probably illustrate two different chemical cycles; one the sulphate cycle;

the other the sulphide cycle. This difference probably obtains for the district as a whole, as in most cases the field-evidence seemingly favors the introduction and deposition of the ores in the form of original sulphides, while in several places in Virginia the very close relation of the ores, with certain layers of the limestone containing organic matter, favored the introduction of the ores in the form of sulphates and their reduction by the organic matter and deposition as sulphides.

(c) *The Holston River Area, Knox and Jefferson Counties.*—The greatest development work in the Tennessee district has probably been done in the Holston River area, which extends from 4 miles east of Knoxville for more than 20 miles northeastward, paralleling the Holston river and the Southern railway. Considerable prospecting, in the form of drilling, is now in progress over most of the area. The principal mines in this area that were formerly worked, or are at present working, are grouped near the following stations on the Southern railway: Jefferson City (Mossy Creek), New Market, Mascot, McMillan and Caswell, with some prospecting on Loves creek, 5 miles northeast of Knoxville. These are taken up in their order and described in some detail below.

(d) *Jefferson City (Mossy Creek).*—The Mossy creek zinc-mines are located on the southeast edge of Jefferson City, directly on the east side of Mossy creek, and about 500 ft. southeast of the Southern railway. These mines mark the first discovery of zinc-ores in Tennessee, during the period from 1856 to 1858. The first mining of the ores is reported to have been in the year 1868, but systematic mining did not begin until 1881, and was continued until 1893. Work was again resumed for one year in 1901.

The workings comprised open cuts and pits, tunnels and shafts, from which a very large quantity of ore was mined. At the time of my visit, in April, 1905, the mine-openings were largely filled with water, and were only partly accessible. The greatest depth reached in mining is reported not to have exceeded 90 ft. During the period of early mining the production in soft ores of great purity, carbonate and silicate, was considerable. The residual decay, red clay, which covered the soft ores, was not so deep, nor was the underlying limestone surface of the pinnacle or "chimney" structure, as at the Bertha and Austinville mines in Virginia. At present the mine openings at Mossy creek do not expose greater depths of the residual clay than 30 ft., and, as a rule, much less.

The country-rock is the characteristic Knox dolomite, light gray in color, of semi-crystalline texture, and contains nodules and masses of chert. In the open work at the mines the rock has been profoundly crushed and broken, and the fragments cemented by white crystallized calcite and dolomite. In large masses the calcite-dolomite filling develops the typical rhombohedral cleavage. An analysis made of the calcite part of the filling or cement gave the following results:

	Per Cent.
Calcium carbonate ($CaCO_3$),	93.71
Magnesium carbonate ($MgCO_3$),	0.84
Ferric oxide $\left\{ Fe_2O_3 \right.$ Alumina $\left. Al_2O_3 \right\}$,	0.22
Insoluble residue,	6.08
Total,	100.85

Blende is the ore in the unaltered limestone. Neither galenite nor pyrite was observed. The blende is usually yellow in color, and its principal occurrence is in disseminated form through the calcite-dolomite filling of the limestone breccia. At times, more or less replacement of the limestone-fragments by the blende is indicated, and not infrequently the fragments are partially rimmed by the blende. This relation of the ore to the calcite-dolomite filling and to the limestone-fragments, shown in Figs. 10, 11 and 16, indicate that the ore is of the disseminated breccia type. It is confined to the breccia-zone, which has a nearly N–S. direction, and marks the plane of a large fault.

A mill was formerly operated at the mines, but it has been dismantled since mining was suspended.

(e) *New Market.*—The Ingalls mine, located on Lost creek, about 2 miles southeast of New Market, has produced large quantities of ore. Considerable work has been done, comprising several large open pits or quarries extending some depth into the hard and unaltered limestone. The limestone is the Knox dolomite of the same general character as described above at the Mossy Creek mine. The beds are rather flatter here than at some of the mines further southwest, showing an average dip of about 20° SE., and strike N. 65° E., which develops a small anticline at this point. The strata have been broken and the fragments recemented by white crystallized calcite and dolomite. It is along this breccia-zone, which here averages probably not more than 50 ft. wide, that the ores have been localized and deposited. In occurrence the ore is quite similar to that at Mossy creek, and it is of the same type. At both places the indications are that the sulphide ore was introduced and deposited simultaneously with the calcite-dolomite filling, cementing the limestone fragments.

The ores comprised carbonate and silicate forms in the oxidized zone and yellow blende in the unaltered limestone. A little pyrite occurs, but galena is essentially absent. Ingalls[8] records the following analyses of ores from this mine:

Smithsonite.	Per Cent.	Sphalerite.	Per Cent.
$ZnCO_3$,	83.29	ZnS,	84.75
SiO_2,	13.10	SiO_2,	7.57
$FeCO_3$,	1.32	$\left.\begin{matrix}Fe_2O_3\\Al_2O_3\end{matrix}\right\}$,	1.66
Fe_2O_3,	0.66		
$CaCO_3$,	1.07	$CaCO_3$,	5.98
$MgCO_3$,	0.56	$MgCO_3$,	0.04

(f) *Loy.*—The mines, located about one mile slightly south of east from New Market, comprise two sets of openings, worked at different times, and separated from each other by a distance of less than one-quarter of a mile along a NE–SW. direction. The easternmost openings were worked for a period of from 12 to 15 months in 1892, when much calamine and smithsonite were reported to have been mined and shipped to Marion, Ind. The depth reached in mining extended for some distance into the fresh limestone, but did not exceed a total of 50 ft. The openings are made in a breccia-zone, and the fresh rock shows yellow blende of similar character and occurrence to that described above at the Ingalls and Mossy Creek mines, but probably leaner. Neither galenite nor pyrite was noted.

The westernmost openings are made in the residual clays mantling the limestone, for mining the soft ores. Work was begun about 15 months ago, and was in progress at the time of my visit, in April, 1905. About half a dozen cars of soft ores, carbonate and silicate, principally the latter, had been shipped to the Bertha furnaces at Pulaski, Va. Average returns from the last car of ore gave 44.20 per cent. of zinc. The thickness of the residual mantle will not exceed 40 ft., but the conditions seemingly favor a rather large area of concentrated soft ores derived in the usual way by weathering from the sulphide, sphalerite.

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[8] *Production and Properties of Zinc*, p. 198 (1902).

About two miles southwest of New Market, near Friend's Station, recent prospecting indicates the presence of blende in the magnesian limestone.

(g) *Mascot.*—The property of the Roseberry Zinc Co. is located about one mile west of Mascot, between Roseberry creek and the Holston river. For about a year this company has been constantly drilling its property, with encouraging results. At the time of my visit, in April, the work comprised one large opening, a number of smaller openings, and a shaft which had reached a depth of 116 ft., penetrating 30 ft. of residual clay and the remaining depth of brecciated limestone. Ore was found at a depth of 104 ft. The shaft has been continued to a depth of 172 ft., drifting on a 14-ft. face of ore, which averages from 12 to 15 per cent. of zinc, and producing a concentrate of about 60 per cent. of zinc.[9]

The large opening, which was worked to some depth in the limestone, exposes a typical breccia of the same character described above. Blende is the ore, and it is associated with the calcite-dolomite filling or cement; disseminated, as a rule, through it in fine granular form, and as irregular small crystalline masses. Galena seems not to occur, but quite a sprinkling of pyrite is found in places. A common occurrence of the ore is that of filling the cracks in the crushed limestone by it and calcite-dolomite. As a rule, replacement is only slightly indicated. Large quantities of soft ores are reported to have been mined some years back.

The dip of the limestone-beds varies, giving a probable average of 20° SE., with much steeper inclinations noted in places; strike N. 35° E. At one point a crust or druse of small gypsum crystals was noted.

A commodious mill, equipped with the necessary jigs, breakers, rolls and tables, is in operation. The ore is free from such impurities as barite, pyrite and fluorspar, which at times are sources of much trouble in some ores, but its fine-grained disseminated character requires fine crushing and very careful milling, with jigs and tables, in order to free it from the limestone and give a clean concentrate.

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[9] *Engineering and Mining Journ.*, vol. lxxx., No. 7, p. 311 (August 19, 1905).

(h) *McMillan, Caswell and Loves Creek.*—Less than half a mile north of McMillan some open work and drilling have recently been done, exposing yellow blende in a brecciated dolomite, similar to the occurrences described above. Galenite and pyrite do not occur. Measurements of the limestone beds gave an average dip of 25° SE. and a strike of N. 45° E.

Drilling was in progress in April about half a mile northeast of Caswell with reported favorable indications.

About 5 miles northeast of Knoxville, on the north side of the Southern railway, and on both sides of Loves creek, some open work has recently been done. Here the dolomite is brecciated, and it contains thin masses or leaves of greenish shales that are much crushed. Considerable chert is contained in the limestone, and in several instances blende in association with the chert was observed to be partially altered to calamine. Galena and pyrite are absent. The limestone beds show a strike of N. 65° E. and dip from 30° to 35° SE.

(i) *Other Localities.*—In Blount county, across the Tennessee river and south of Knoxville; and in Bradley county, from 20 to 30 miles east of Chattanooga, galena is found in a number of places in sufficient quantity to make mining profitable. Mining and prospecting, where galena is found in these counties, indicate that the ore is disseminated through the Cambro-Ordovician limestone (Knox dolomite). In Bradley county the ore occurs most abundantly near the base of the Knox dolomite, and in the heavy blue limestone at the top of the Conasauga shale (Cambrian). For some years galena has been mined and smelted at Blue Springs, a station on the Southern railway, about 6 miles south of Cleveland. Similar conditions to those at Blue Springs are found in many places over the area, and doubtless future prospecting will reveal valuable deposits.

Recently, prospecting has been quite active over a considerable part of Blount county, and in many places the results are very encouraging. The Valley Mount Lead Co. has done considerable work in the way of cuts, tunnels, etc., and is now preparing to drill its property. The occurrence of the ore is reported to be similar to that of southeastern Missouri, but it carries a higher percentage of lead than the latter. At the Cedar Ridge mine, where some work in the form of cuts and shafts has been done, the indications are that drilling will probably prove the property to be a valuable one. Prospecting, sufficient only, as a rule, to indicate the presence of lead-ore, has been carried on at several points in the county, principally along and near the Louisville and Nashville railway.

XVII. General Conclusions Regarding the Ores.

From the previous description and discussion the following conclusions seem to be warranted:

1. The zinc- and lead-ores of the Great Valley region of Virginia-Tennessee were originally deposited with the limestone in which they were subsequently localized and concentrated and are now found. Unlike the deposits of this district, the one in Albemarle county, Va., occurs in crystalline schists, and was probably genetically connected with igneous intrusions.

2. The district is one of intense deformation,—folding, faulting and brecciation. The ores are closely associated with the faulting and folding, and are of the disseminated replacement breccia type.

3. The accumulation and concentration of the ores as they are now found were by circulating underground waters. These were probably transported in the form of both sulphates and sulphides; and they were precipitated and deposited in their present position partly by organic matter and partly by the mingling of solutions and the reaction of the ore-bearing solutions on the wall-rock, limestone.

4. From the character of the metallic sulphides and the associated minerals, neither a profoundly deep circulation of underground waters nor of a circulation connected with igneous rock-masses, was responsible for the deposition of the ores.

5. The associated minerals of the non-metallic type include dolomite and calcite in crystalline form as the principal ones, with a little fluorite, quartz and barite found in several places in the Virginia area.

6. Replacement has been an important process in the for-

mation of the ores over a part of the district. The common evidences of sulphide enrichment are lacking, and the sulphide ores are regarded as the products of a first or primary concentration.

7. The soft or oxidized ores, carbonates and silicates, were produced by the alteration of the original sulphide ores, galenite and sphalerite, in the zone of oxidation.

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SUBJECT TO REVISION.

[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

The Mining, Preparation and Smelting of Virginia Zinc-Ores.

BY THOMAS LEONARD WATSON, VIRGINIA POLYTECHNIC INSTITUTE, BLACKSBURG, VA.

(Bethlehem Meeting, February, 1906.)

INTRODUCTION.

IN a paper read by title at the Washington meeting of the Institute,[1] May, 1905, I discussed at considerable length the geological relations, mode of occurrence, and the genesis of the lead- and zinc-ores of the Virginia-Tennessee region. The present paper treats of the purely economic phases of the zinc-ores of the district; such as methods of mining the ores, their preparation and treatment. The Albemarle county mines and plant were discussed in the paper referred to above, and will not be considered here.

METHODS OF MINING.

Until very recently the mining of lead- and zinc-ores in Virginia was limited wholly to the surface belt of weathering. The mode of occurrence and the character of the ores to be mined were such as to demand the employment of methods used in mining secondary concentrated ores. Accordingly, a system similar to that practiced in mining brown iron-ores was employed, being modified to meet the changed conditions.

Oxidized or Soft Ores.—Up to the present time practically all the ore mined in the Virginia district has been of the oxidized or soft type;—the silicate, calamine, and the carbonate, smithsonite; largely the former, which has been localized and concentrated at only slight depths below the surface. Because of the extreme irregularity with which the limestone weathers when stripped of the overlying residual clay, it presents a roughened surface of large and small irregular "chimneys" and pinnacles of the hard rock, as shown in Figs. 1 and 2. It is in the depressions between the pinnacles, and extending some distance up and on their sides, occasionally passing over the pinnacles from bottom to top, that the ores have been concentrated. The ores hug somewhat closely the irregular surface of the limestone and are overlain by the clay. In this mode of occurrence the ore averages from 1 to 25 ft. in thickness, and its depth below the surface will not exceed 80 or 90 ft., usually much less.

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[1] Lead- and Zinc-Deposits of the Virginia-Tennessee Region, *Bi-Monthly Bulletin*, No. 2, March, 1906, p. 139.

Such an occurrence favored the working of the ores in the beginning by the method of "open-cut" mining, the usual method practiced in the region for mining the brown iron-ores

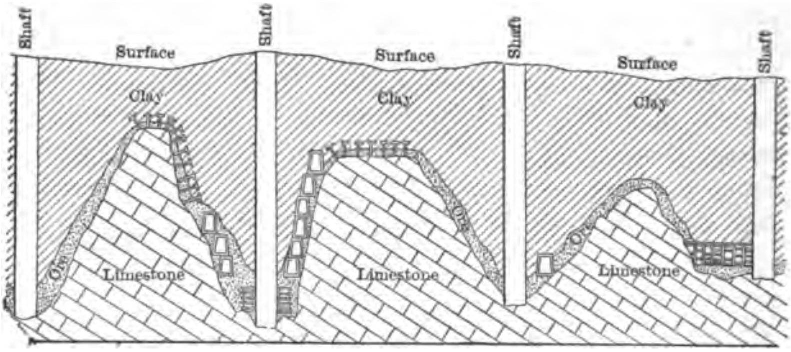

Fig. 1.—Section Through the Bertha Zinc Mines, Showing Occurrence of Zinc-Ore in Relation to the Limestone and Clay, and the Method Formerly Employed in Mining the Ore. (Modified from Fig. 7, of Mr. Case's paper, *Trans.*, xxii., 524.)

(limonite). The open-cut method of mining the zinc-ores differs, however, from that of mining the iron-ores, in that the former is one essentially of stripping, while in the latter the ores and inclosing clays are mined together and sent to the washer for separation.

At Bertha, the most systematically worked of the Virginia soft ore zinc-mines, the method of open-cut mining was followed until the fall of 1889, when a change was made. The difficulties of the open-cut mining at Bertha were numerous, and, as the work progressed, these, added to the increased cost of removing the clay, necessitated a change in the method. The chief object, however, in making this change was to secure a steady and sufficient output for the furnaces, as well as to lessen the cost of mining. Accordingly, a system of underground mining was introduced, the ore being reached through shafts 3.5 ft. in diameter sunk in the clay. Inexpensive plank shafts of 38 in. square, inside diameter, were also used. These were sunk to the limestone bottom at the deepest points. Timbered drifts were then driven in the ore, following it around the "chimneys." When the chimneys were thus encircled at a given level, a second drift was established or run upon the ore below. In this way drifts, one after another, were carried around and over the chimney until all the ore had been entirely removed from it. This method of mining is illustrated in Fig. 1, which is a modification of Fig. 7, in the paper by Mr. William H. Case.[2] Fig. 2 is a photographic view of the "chimneys" at Ivanhoe, Va. The ore was wheeled to the shafts, where it was loaded into iron buckets and hoisted by steam-power. It was then dumped into cars of about 2 tons' capacity, and carried by a locomotive to the dumps at the head of the water-carriage. The ore, as thus mined, was reported to have contained about 26 per cent. of metallic zinc.

On the Lead Mine tract at Austinville, 10 miles west of Bertha, lead- and zinc-ores above ground-water level have been mined for 150 years. Large quantities of the ores have been removed, mined principally by the open-cut method. Much underground mining was done above ground-water level, consisting of shafts, drifts and stopes, reaching a maximum depth of 250 ft. Both the open-cut and underground mining have been done without any apparent system. The soft lead-ores were mined on this tract for a long period of years before attention was given to the zinc-ores, if, indeed, they were recognized at all.

The method used in mining the lead-ore seems to have been that of following the ore, by irregular underground openings, down from the surface through the clays wherever found, resembling a very crude form of stoping. Ordinarily, little or no timbering was done, regard being had only for the present mining of the ore.

The Sulphide Ores.—Practically, no sulphide ores have been mined, and, apart from prospecting and development-work, practically no underground mining in the hard rock, limestone, has been done. This has been due, not to a lack of the sulphide ore, blende, in the limestone, but to the fact that the soft or oxidized ores within the belt of weathering were adequate for the needs of the furnaces. Now that the known areas of soft ores seem very limited, considerable exploitation of the sulphide ore-bodies in the hard limestone is in progress over the Virginia-Tennessee region. In Virginia the outlook is very encouraging at Austinville and Cedar Springs in Wythe county, and at several points in Rye Valley in Smyth county. In Tennessee equally promising results are indicated in three areas:—the Holston River area in Knox and Jefferson counties, the Straight Creek area in Claiborne county, and the Powell River area in Union county.

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[2] The Bertha Zinc-Mines, *Trans.*, xxii., 511–536 (1893).

PREPARATION AND SMELTING OF THE ORES.

Washing and Milling.—The preparation and treatment of the ores can best be explained by describing the methods formerly used and at present practiced at the two largest worked and the most extensive mines in the Virginia district, namely, Bertha and Austinville. At Bertha, mining for zinc-ores has been discontinued, and the mines are now being worked for brown iron-ore. However, a description of the former treatment of the Bertha zinc-ores will be of interest at this time.

The Bertha Ores.—The mining of zinc-ores at Bertha was stopped in 1898, when the property was leased to the Pulaski Iron Co., for the purpose of mining iron-ores. The hope exists, however, that more available zinc-ore will be found when the covering of iron-ore has been removed.

Two storage-bins for receiving the ore as mined were built on the bluff overlooking New river, about 0.75 miles from the mines. These were built on timbered trestles leading out from the hillside, and were provided with V-shaped floors, down the center of which passed a cast-iron water-trough, 12 in. wide and 6 in. deep. The ore was hauled from the mines to the bins in tram-cars, where it was fed into the water-trough and carried thence by a current of water to the dressing-house, 13 ft. below. The water used was pumped into a large tank above the bins on the hilltop, and there stored and fed as required. The inclined plane between the troughs was used to hoist, by steam, timbers and supplies for the mines.

The dressing-house was a three-story building, reported to have been well equipped with all the necessary automatic machinery for the concentration of zinc- and iron-ores. The zinc-ore was brought down the trough, falling upon a grizzly, through which the large lumps were broken. All the material was then passed into a single log-washer, where it was given a gentle sluicing, to free the ore from adhering clay.

Because of its porous structure and the clay contained in the cavities, it was necessary to treat the lump-ore further by passing it through a Blake breaker and a pair of Cornish rolls. From the rolls the ore passed to conical revolving-screens, where it was sized; the large pieces dropped upon a steel-plate conveyor and were hand-picked. The small pieces passed down to four sets of Parson jigs, on which they were thoroughly concentrated. The tailings, resulting from this treatment, were passed through a spitzkasten or classifier, and thence to two Harz jigs. The slimes were discharged into a slime pond, from which the muddy water was drained off into the river.

The capacity of the dressing-house is reported to have been 80 tons of concentrated zinc-ore per day of 10 hr. The yield is said to have been approximately one-third of the crude ore treated, and the product, dried at 212° F., is reported of the following average composition:—

Zn (metallic), 38.08; ZnO, 47.61; SiO_2, 29.37; Fe_2O_3, Al_2O_3, 9.23; $CaCO_3$, 4.54; $MgCO_3$, 2.07; H_2O (combined), 8.23; Pb, tr.; total, 101.05 per cent.

A roasting plant, consisting of an 8-ft. Taylor gas-producer and a 30-ft. cylindrical roaster, was operated for expelling the moisture from the ore.

The Austinville Ores.—The run-of-mine ore at Austinville is said to average in composition from 28 to 30 per cent. of zinc (metallic), from 8 to 10 per cent. of lead (metallic), and from 8 to 10 per cent. of iron (metallic). A brief sketch is here given of the method of treating the Austinville ore from the time it is mined until it is ready for the furnaces at Pulaski. A general view of the Austinville Zinc- and Lead-Mines plant is given in Fig. 3.

The ore, as mined, is carried by trolley to tipples; from whence it is carried by tram-cars to the mill, and dumped on a 4-in. grizzly; thence to a log-washer through a 9- by 15-in. Blake breaker set at 1.5 in.; and thence to 14- by 24-in. corrugated rolls set at 6 mm. From the corrugated rolls the ore is carried to a second log-washer, thence to elevator and sizing-screens of 6-mm., 2-mm., and 1-mm. mesh, respectively.

The oversize from the 6-mm. screen goes to smooth rolls, 12 by 18 in. in size, and is returned to the system or second log-washer. The undersize from the 6-mm. on 2-mm. screen goes to the 4-compartment Cooley jigs; 1st hutch and side-draw making clean lead; 2d hutch and side-draw, middling, recrushed and returned to the system or second log-washer; 3d and 4th hutches, clean zinc. Tails are passed to settling-boxes; head of boxes reworked. Lighter material goes to the oxide furnaces.

Undersize from 2-mm. on 1-mm. screen goes to the 5-compartment jigs; 1st and 2d hutches and side-draw making clean lead; 3d hutch and side-draw, middling; 4th and 5th hutches and side-draw, clean zinc. Tails go to boxes.

Undersize from 1-mm. screen goes to a 3-compartment classifier; 1st and 2d draw to 6-compartment jigs; 1st and 2d hutches and side-draw making clean lead; 3d and 4th hutches and side-draw, middling; 5th and 6th hutches and side-draw, clean zinc. Tails go to boxes.

Third draw from classifier and overflow goes to the 3-compartment double jigs; 1st and 2d hutches making clean lead; 3d hutch, middling, reworked. Tails go to boxes.

The middlings and tails from all jigs are treated in 4-compartment jigs, as described above. The overflow from 1st and 2d log-washer, except the lower end or lighter material, goes to settling-boxes, 25 ft. long and 8 ft. wide; thence to the oxide furnace.

The lead-concentrates, averaging,—lead, 57; zinc, 4.8; and iron, 3.29 per cent., go to the Scotch hearth furnace, which makes metallic lead and gray slag, the latter averaging,—lead, 31; zinc, 25; and iron, 13.3 per cent. This slag goes to the slag-furnace, which makes metallic lead and slag, averaging 3.5 per cent. of lead.

The zinc-concentrates are carried by tram-cars from the mill

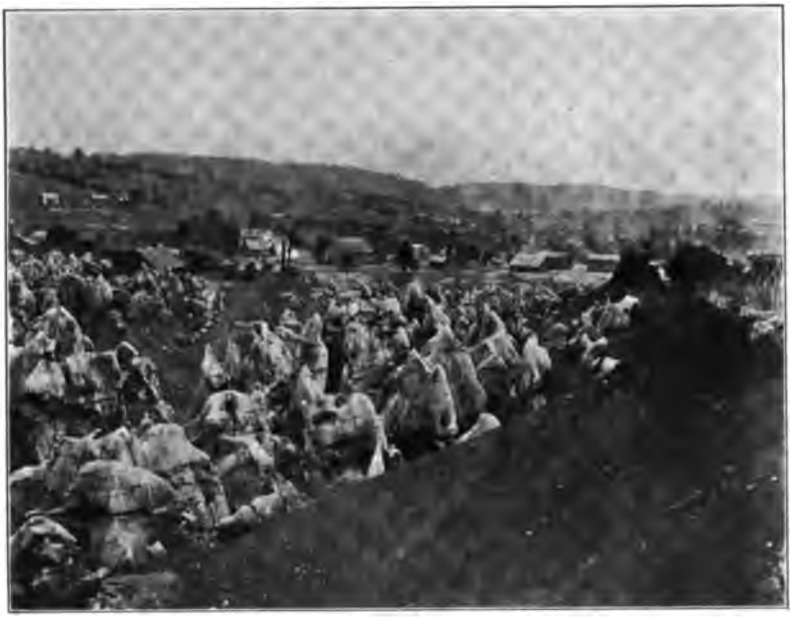

FIG. 2.—GENERAL VIEW IN THE MINE OPENINGS AT IVANHOE, VIRGINIA, SHOWING THE IRREGULAR WEATHERED LIMESTONE SURFACE INTO PINNACLES OR "CHIMNEYS." (Photograph by H. Ries.)

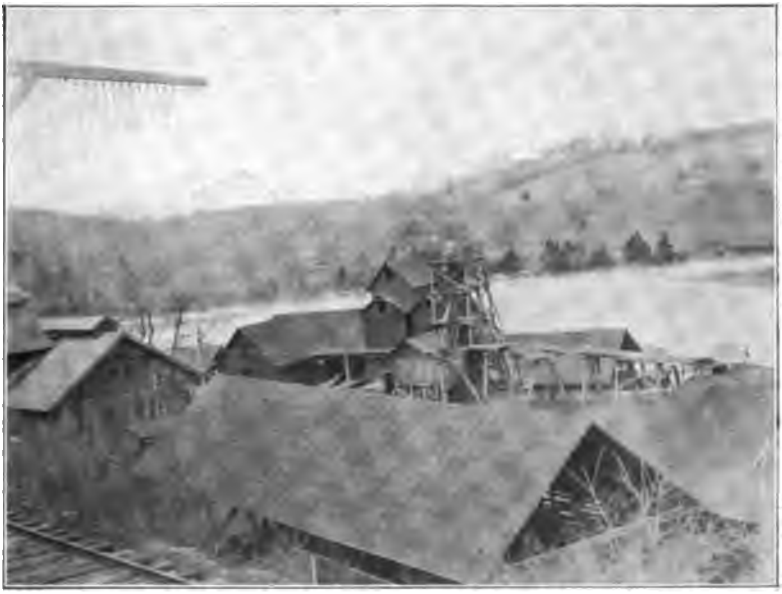

FIG. 3.—GENERAL VIEW OF THE AUSTINVILLE ZINC- AND LEAD-MINES PLANT.

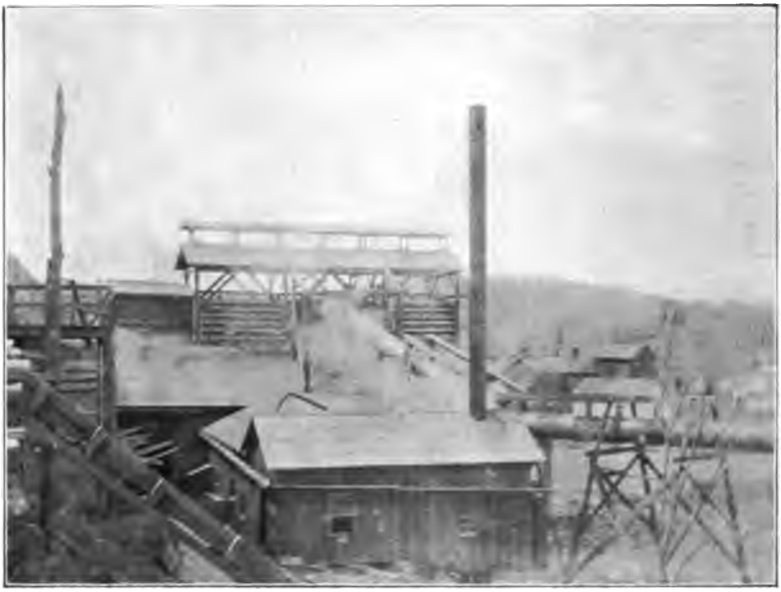

FIG. 4.—THE OXIDE FURNACES AT AUSTINVILLE, VIRGINIA.

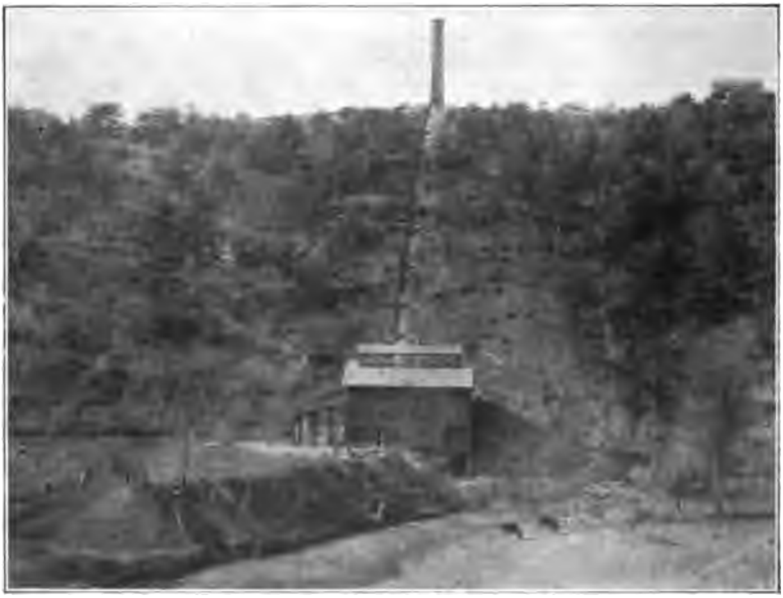

FIG. 5.—ROASTING FURNACE FOR TREATING ZINC-SKIMMINGS.

to the separators, where they are put through a revolving dryer to expel moisture and combined water to the amount of 7 per cent. Thence to a water-cooled scraper-conveyor to the top of building by elevator to sizing-screens of 0.5-mm., 1-mm., 2-mm., and 0.25-in. holes. Oversize from 0.25-in. screen is returned to 12- by 14-in. rolls set close. Undersize re-enters the system. From screen to bins, four sizes.

The four sizes, which pass through screens, go to Wetherill magnetic separators, one 4- and one 6-magnet machine; the smallest sizes going to the smaller machine. Heads from separators, containing iron, 47, and zinc, from 5 to 7, per cent., are shipped to the iron-furnace. Tails from separators, containing zinc, 43.5; iron, from 5 to 6; and lead, 15 to 20 per cent., are shipped to the zinc-furnace. The capacity of the mill is about 90 tons of raw ore per day of 10 hours.

Zinc Oxide Plant.—This plant, consisting of 12 furnaces, has only recently been added, mainly for the purpose of utilizing the low-grade ore and tailings, which were formerly discarded. After thorough testing, the plant has proved entirely satisfactory. The grade of ore, including tailings used for making the oxide, will average from 15 to 20 per cent. of metallic zinc. The zinc oxide is conducted from the furnaces, through a 3-ft. iron cylinder, 600 ft. long, where it looses nearly all of its heat in transit, into bags. At present, the zinc oxide is sent to the Pulaski furnaces, where it is used for making spelter. No attempt is made to purify the zinc oxide sufficiently to market it as zinc-white. As now made, the zinc oxide is white, contains about 4 per cent. of lead, and averages from 70 to 80 per cent. of metallic zinc. A view of the zinc oxide plant at Austinville, Va., is given in Fig. 4.

The successful operation of this plant at Austinville is of great importance, since it conclusively points out a method for utilizing low-grade zinc-ores, which elsewhere, it is claimed, cannot be profitably worked for making spelter.

THE BERTHA SMELTING-PLANT.

Location and Equipment.—The only zinc-smelting plant in the South, located at Pulaski, Va., is owned and operated by the Bertha Mineral Co. This plant was built soon after the beginning of zinc-mining at Bertha, Wythe county, Va., in 1879.

It was remodeled and enlarged in 1886, and, at present, it consists of 10 large smelting furnaces, ore-sheds or bins, refiners, coal-pit, engine-room, pottery, metal-storage houses, and a roasting furnace. Sufficient railway-trackage is in operation around the plant for shifting the cars; and a narrow-gauge road is operated between the plant and the company's coal-mine at Altoona, from which all the coal formerly used was derived; but, at present, only the "firing" coal or reducing-material is obtained.

Furnaces.—The 10 furnaces are of the Belgian type, hand-fired, built in 5 blocks of 2 furnaces each, placed back to back. The furnaces are 8 ft. deep, 30 ft. wide, and 24 ft. from top to bottom of foundation. They have an average capacity of 20,000 lb. of spelter every 24 hr. The capacity of each furnace varies from 1,800 to 3,000 lb. of metal per 24 hr., depending on the grade of ore used. Each furnace consists essentially of a large skeleton combustion-chamber, lined in the back with fire-brick, and having an iron frame-work front. The retorts are inserted from the front, with the back ends resting on a fire-brick support, built out from the back lining, so that when in position the retorts incline slightly toward the front of the furnace. Each furnace is fitted with 140 retorts, arranged in seven rows of 20 each.

The grates, placed from 3.5 to 4 ft. below the lowest row of retorts, are from 10 to 12 in. wide and 13 ft. long. A peculiarity is that the grates have, beside the three solid bars placed lengthwise, two hollow bars, arranged one on either side next to the wall. These are charged by water under pressure. Along the tops of the hollow bars are perforations, through which the water escapes when it is turned on at intervals. These water sprays strike the under side of the cinder, forming on the grate, and serves to break it up thoroughly, so that the ash is fine and pulverulent. This produces a clear fire and a cool ash-pit. Pocahontas coal is used, and, on account of its high grade and the clean grates resulting from the use of the water spray, described above, its consumption is low. A fairly uniform heat is obtained over all the furnaces.

The fire-boxes are narrow, deep and long. The furnaces are fired from either end, the entire length of the grate-surface being 26 ft., with a sloping divide in the middle, and chimney-draft. A very heavy bed is used, so that each furnace practically becomes a gas-producer. The doors are closed, and air is introduced through small holes in the front of the furnace, which can be closed as needed. Additional draft is provided above the furnace for regulating the heat.

Retorts and Condensers.—The retorts used are either round or oval. The dimensions of the round retorts are:—length, 4 ft. 2 in.; inside diameter, 8 in.; thickness, 1.5 in.; capacity, 1,251 cu. ft. The oval or elliptical retort, of a capacity of 1,228 cu. ft., is placed on the lower rows of the furnace, each retort being so placed that its greater diameter is in a vertical position. The retorts were all made at the company's plant on a Wooley tile-machine, of a capacity of 100 retorts per day of 10 hr. These retorts are made from the best-grade of St. Louis, Mo., fire-clay, which is, perhaps, not so refractory as some other more siliceous clays, but is regarded as the best material for this purpose.

After coming from the machine, the retorts are arranged in a drying-room for two weeks, and held at a constant temperature of about 80° F. They are then placed in a second room, the temperature of which is 100° F., where they are kept for two months. Just before being placed in the furnace the retorts are stacked in kilns and fired for 16 hours.

The condensers are 21 in. long and 3.5 in. in diameter at one end, the other end being slightly smaller than the retorts. These are all made of local clay, mixed with that from grinding the old retorts. Shortly before being used or placed in position, they are washed inside with a mixture of water and fire-clay, in order to prevent the metal from soaking into them. The retorts are luted to the condensers with a mixture of one-third clay and two-thirds coal; enough water being added to bring the mixture to the proper consistency.

Materials Used in Charging.—At present, the materials used in charging are:—local ores, including the silicate and carbonate of zinc; crude zinc oxide, containing from 70 to 80 per cent. of metallic zinc, and made from local ores at Austinville; willemite, anhydrous zinc silicate, from Franklin, N. J., averaging 48 per cent. of metallic zinc; zinc flue-dust from the iron-furnaces; and zinc-skimmings from the galvanizers, which are first given a preliminary roast in a special furnace in order to drive off the ammonia and chlorine. The zinc-skimmings are easily fired, and are usually smelted alone. No sulphide ores are handled at present. Fig. 5 is a view of the furnace for roasting zinc-skimmings.

As a rule, the ore, as delivered at the plant, is ready for the furnaces; it being sized to pass about a 6-mm. mesh screen. Some lump ore, however, is received, which is crushed and sized to an ⅛-mesh size before using. The retort-charges are usually mixed, though some of the furnaces, as occasion demands, are run on special material alone, such as the zinc oxide from Austinville. The only difficulty in smelting the oxide alone is the slight tendency to "ball up," which makes it necessary to introduce a mechanical mixer in order to produce a more intimate contact between the ore and the carbon. For this reason the oxide is usually mixed with some ore before smelting.

The charges, consisting of ore and fuel, mixed in the proper proportions, are wheeled to the furnaces, moistened with water, and mixed on the hearth by shoveling. The charges are all mixed by weight. At present, the oxide, willemite, crude ore, coal and coke are mixed on the hearth, as described, and used for charging. The mixture and fuel are charged tightly into the retorts; a condenser is then inserted into the mouth of each retort, and luted and sealed perfectly tight.

Distillation and Tapping.—The furnaces having been made ready and fired, the reduction of the zinc in the retorts takes place according to the following formula: $ZnO + C = Zn + CO$. The CO acts as a further reducing agent, thus: $ZnO + CO = Zn + CO_2$. The zinc vapor passes from the retorts into the condensers, where it collects in the form of molten metallic zinc. There are three taps made during a run of 24 hr. After the last tap is made, the fires are allowed to slacken, the condensers are removed, and the retorts are thoroughly cleaned with an iron rabble. Each retort is inspected with a hook before recharging, so as to be sure of its being thoroughly clean; and it is also inspected for holes and cracks. It is claimed that the retorts cannot be cleaned by blowing out with steam, as practiced in the West, on account of the siliceous character of the materials used. The time required to complete the process at the Virginia furnaces is longer than at the western furnaces, so that, in the case of the former, the furnaces are cooler for a longer time than at the western ones. The breakage of retorts is small, being only from 0.6 to 0.9 per ton of ore smelted.

Spelter.—Three grades of spelter are produced, branded, according to purity: "Bertha Pure Spelter;" "Old Dominion" and "Southern." The Bertha Pure Spelter has a world-wide reputation, and is sold under guarantee of 99.98 per cent. of metallic zinc. The following analyses afford an excellent idea of its purity:—

	Sample I.	Sample II.	Sample III.
Zinc (by difference),	99.949	99.981	99.963
Iron.	0.010	0.019	0.012
Lead,	0.035	trace	0.012
Sulphur,	none	trace	0.001
Silicon,	0.206	none	0.202
Carbon,	trace	none	none
Arsenic,	none	none	none

As will be noted from the above analyses, the Bertha Pure Spelter is practically free from all impurities. It is extensively used abroad and in the United States for Government work. It is produced, in part, directly from the furnace; but it can be produced from either of the other brands, Old Dominion or Southern, by refining in a special patented furnace, in which the metal is redistilled carefully in order to avoid carrying over any of the lead. The Old Dominion brand of spelter contains from 0.2 to 0.4 per cent., and the Southern brand from 0.8 to 1 per cent. of lead.

The plant of the Bertha Mineral Co. is famed for the high-grade of its spelter. To some extent this is due to the purity of the materials used, being specially free from iron, and to the fact that carbonate and silicate ores only have been used; the chief reason, however, is because of the good furnace-work.

TESTS.

Some very interesting and important tests at the Pulaski plant have recently been conducted on low-grade mixed ores. One of the most important of these was on a lot of mixed carbonate and sulphide ores from north Arkansas. It was found necessary, first to give the mixture a roast in order to desulphurize the blende present in the mixture. By giving the mixture a slow roast the sulphur was driven off without loss of the zinc in the carbonate, and, at the same time, the carbonate was benefited by having the carbon dioxide expelled. The success of this experiment has resulted in the willingness of the Bertha plant to treat the Arkansas ore, which, at present, is somewhat of a drag on the Western market. This probably opens up a better future for the Arkansas ores, and, at the same time, points to an additional source of ore-supply for the Virginia plant.

Whenever it was possible to get it, Tennessee ore has been used. However, the lime present in the Tennessee sulphide ores seems to interfere with the work, since, by desulphurizing the ore, calcium sulphate is formed, which cannot be removed. Perhaps the principal reason for this is the finely disseminated character of this ore. This objection can be met, however, and a reasonably clean concentrate carrying little or no lime can be produced, by carefully milling, jigging and tabling the ore.

The Bertha Mineral Co. has not been producing ore from its property during the past year, for the reason that it has been and is still engaged in exploiting and developing the very promising bodies of sulphide ore at Austinville.

FUTURE DEVELOPMENT.

From the beginning of mining zinc-ores in southwestern Virginia to the present time, about 35 years, attention has been given exclusively to the removal of the soft or oxidized ores, the carbonate and the silicate. Now that the known supply of these ores in the district is rapidly diminishing, the problem in the future will be that of mining sulphide ores. Already considerable activity is manifested over both the Virginia and Tennessee districts in prospecting for and developing sulphide ores. Very encouraging results are obtained in places, and there seems sufficient reason for regarding the district as a promising one for workable bodies of sulphide ores.

The very favorable location of the district as regards abundant fuel-supplies, cheap labor and ample transportation-facilities, should make it possible to work lower-grade ores more profitably than in many of the central and western districts.

The ores yet found are in the Shenandoah limestone, or its equivalent in East Tennessee, the Knox dolomite. The Shenandoah limestone includes all of the Knox formation and at least 1,500 ft. of Cambrian strata beneath it. The ores apparently extend from near the bottom to the top of the limestone, and they are closely associated with the folding, faulting and brecciation of the district.

TENNESSEE.

Conditions similar to those in Virginia exist in the Tennessee district. The same ores are found, and, as in Virginia, much of the zinc-mining in Tennessee has been done on the soft ores, smithsonite and calamine, which are alteration-products from the original sulphide, sphalerite. At the present time, attention has been chiefly directed to the exploiting of sulphide ores, and, during the past 12 or 18 months, much testing has been in progress over parts of the district, principally in the form of drilling. This is particularly true of the Holston River area, in Knox and Jefferson counties, and the results seem quite encouraging. At least two other areas in Tennessee, namely, the Straight Creek and Powell River areas, show equally encouraging results in the presence of workable sulphide ores. From the very nature of the deposits, the methods of mining and preparation of the ores in the two States are closely similar. The Tennessee ores have been shipped, in part, to the Virginia smelter at Pulaski, and in part to the Indiana smelter at Marion.

SUBJECT TO REVISION.

[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

The Kurzwernhart Gas-Saving Process.

BY JOSEPH HARTSHORNE, POTTSTOWNE, PA.

(Bethlehem Meeting, February, 1906.)

EVER since the introduction of the Siemens regenerative furnace, it has been recognized that a certain amount of gas is lost each time the furnace-action is reversed. This loss comes, first, from the gas which passes through the free connection between the stack and the gas-main, which exists during the time the reversing-valve is turning over; and, secondly, from the gas which is in the chamber and flues, from the hearth to the reversing-valve, and which flows back into the stack when the valve is reversed. The amount lost each time is, of course, small; but, since a furnace is reversed from four to six times every hour for, say, 300 days in the year, the aggregate is large enough to be well worth attention. The estimate has been published[1] that, in Germany alone, the loss from the first of the above causes amounts to 500,000 marks per year. The loss from the second cause is, of course, much greater.

A process for saving this entire loss, in use at Teplitz, Bohemia, for about three years, would seem to be of value even in this country, where coal is cheaper and where the small economies are not watched as closely as they are in Europe. This process, invented by Mr. Adelbert Kurzwernhart, late Technical Director of the Teplitzer Walzwerk, has been worked out with thoroughness. The loss from each cause can be calculated very closely for any particular furnace, and the results to be expected from the process ascertained. It can easily be decided, therefore, whether it is worth while to adopt it under any given conditions.

The amount of chamber-gas lost depends upon,—(1), the cubic contents of the chamber, ports and flues upon one side of the furnace, up to the reversing-valve (deducting, of course, the volume of the regenerative brick); (2), upon the temperature of the gas in them; and (3), upon the number of reversals per hour. The amount of coal lost depends upon the number of cubic feet of gas evolved from a pound of it; and the final factor in ascertaining the money loss is, of course, the price of the coal per ton at the producer. All of these factors vary greatly among different works, and the value of the process for each particular case must be determined from the special conditions which there exist.

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[1] *Stahl und Eisen*, March 1, 1903.

The temperature of the gas varies from about 200° C. at the reversing-valve to about 1,100° C. at the ports; 600° C. may be taken as a fair average for the purpose of calculation. In order to establish a fixed basis for comparison, the volume of the gas must be reduced to that at zero C., by the following formula, in which V^1 is the volume of the gas at zero C., $V (= 1)$ its volume at the temperature of the chamber, x is the coefficient of expansion for each degree C., and t ($= 600°$) is the temperature of the chamber:—

$$V^1 = \frac{V}{V + (x \times t)} = \frac{1}{1 + (0.003665 \times 600)} = 0.312.$$

In this country the volume of gas produced from a pound of coal ranges from about 25 cu. ft. for the lignites to about 72 cu. ft. for the best producer-coals. A fair average for the coals in general use appears to lie between 60 and 70 cu. ft. per pound, say 66 ft., although some of the best authorities fix this average at 60. The saving in coal per year, in tons, is then found by the following formula, in which S is the net saving in tons, V is the net cubic content of the chamber, etc., a is the volume of gas, at zero C., from 1 lb. of coal, and n is the number of reversings per hour:—

$$S = \frac{n \times 24 \times 300 \times V \dfrac{0.312}{a}}{2240} = 1.0028 \frac{nV}{a}.$$

For example, assume a 50-ton furnace, reversing four times per hour, and the cost of coal at $2 per ton. The net cubic content of the flues, chamber and ports will be about 3,700 cu. feet. The loss per year will be:—

$$\frac{1.0028 \times 4 \times 3700}{66} \times 2 = \$449.74.$$

If the furnace be reversed six times per hour, as is sometimes done, the loss will then be 50 per cent. greater, or $674.61 per year. Of course, the poorer the coal in gas-producing quality, the greater will be the loss, since more of it is required to produce 1 cu. ft. of gas.

The loss through the reversing-valve depends on its area, the duration of the time of reversing, the velocity of the gas-current, and the temperature of the gas in the flue, together with the amount of gas produced by 1 lb. of coal, and the price of the latter. The loss of coal per year is found as follows: A being the area of the reverse-valve, D the velocity of the current (taken at 15 ft. per second), t the temperature of the gas, n the number of reversings per hour, and a the volume of gas, at zero C., from 1 lb. of coal, the duration of the reversing being taken at 5 seconds:—

$$\frac{\dfrac{A \times D}{1 + (.003665 \times t)} \times \dfrac{5 \times n \times 24 \times 300}{2}}{2240}$$

$$= \frac{\dfrac{A \times 15}{1 + (0.003665 \times 200)} \times \dfrac{n \times 3600}{a}}{2240} = 139.11 \frac{An}{a}.$$

For a 50-ton furnace, with a 30-in. gas-reversing valve, the area of the valve-opening is 4.9 sq. ft., the velocity of the gas-current is about 15 ft. per second, the temperature of the gas is about 200° C., the duration of reversing 5 seconds, and the number of reversings is 4 per hour. The loss per year, with coal at $2 per ton, will then be:—

$$\frac{139.11 \times 4.9 \times 4 \times 2}{66} = \$82.71.$$

If the furnace be reversed 6 times per hour, the loss will be $124.07 per year. The total loss, from both causes, will be, therefore, $532.45, with 4 reversings per hour; and $798.68, with 6 reversings.

The idea of the Kurzwernhart process is to sweep into the furnace and utilize all the gas in the ports, chamber and flues, which is now lost in reversing, and, incidentally, to prevent any loss through the reversing-valve into the stack. This is accomplished by providing an auxiliary air-valve opening into the gas-flue between the furnace and the gas-valve, as near as possible to the latter, and by closing the gas-valve during reversing. The method of procedure is to close the gas-valve just before reversing, as is now quite generally the practice, and then to open the auxiliary air-valve. The air, rushing in through this opening, sweeps all the gas in the flues and chamber into the furnace, where it is burned with useful effect. When all of this gas has been burned, which is easily determined by observation through the peep-hole, the auxiliary air-valve is closed, the furnace is reversed, and the gas-valve is opened as before.

In considering this process, the possible danger of explosion, when the auxiliary air-valve is opened, at once suggests itself. The best comment on this suggestion is the fact, that, during the three years in which the process has been in use at Teplitz, no explosion has taken place. In reality, however, there is no such danger so long as the gas in the reversing-valve is above the temperature at which it will ignite. When it is above this temperature, the gas will always at once ignite along the line of contact as soon as the in-rushing air strikes it. The products of combustion then formed will act as a separating-layer between the gas and the air, and thus prevent further mixing or combustion. Since the gas is pushed through the comparatively narrow flues and chamber with considerable velocity, there is neither time nor space for the dissipation of the separating-layer.

Little, or none, of the gas is, therefore, consumed in the chamber or flues, and there is no danger of burning-out the brick-work more rapidly than usual. Experience has shown that there is no difference in the life of the brick-work whether the process be used or not. Of course, any heat that may be produced by the gas which burns in the valve-casing, or beyond it, goes into the furnace, or is absorbed by the checker-brick, and is thus utilized.

Another possible source of trouble is the leaking of the auxiliary air-valve during the ordinary working of the furnace, more especially because this valve is usually a simple flap. If there be a plenum in the gas-flue, as was usually the case formerly, the only result of such a leak would be a little loss of gas, which would detract just so much from the economy of the process. Under conditions of present practice, however, there is often a slight vacuum in the gas-flue, resulting in a small in-draft through whatever leak there may be. This vacuum should not ever exceed 0.2 in. of water, and probably does not average more than 0.16 in. (4 mm.). If the air so entering be of sufficient quantity, trouble might be caused by combustion, provided it entered the valve-casing, but no calorific loss would result, as stated above, except, possibly, from radiation.

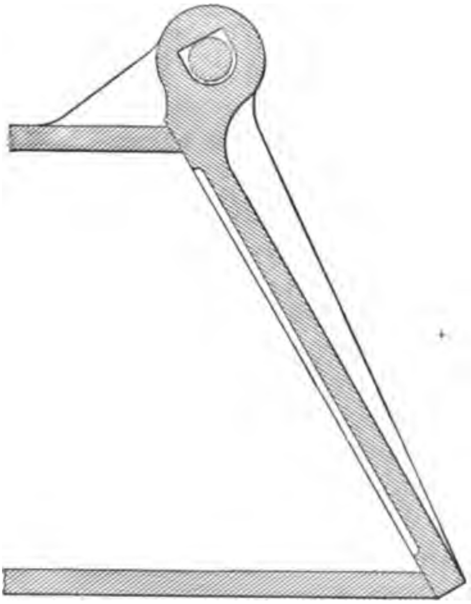

FIG. 1.—SUPPLEMENTAL AIR VALVE.

There is no reason, however, why this supplemental gas-valve should be allowed to leak, even if the most convenient form, that of a flap, be used. Such a valve can easily be constructed so that it will always close tightly, and a simple and effective form is shown in Fig. 1. The flap lies at an angle of about 60°, and is made stiff enough to resist warping under ordinary conditions. The bearing- and seating-surfaces are finished, and enough play is provided between the journal and its bearings to prevent jambing, and to allow the flap to adjust itself by its own weight. The upper part of the journal-bearing is made flat instead of round, to allow this self-adjustment to take place more freely. A valve so constructed will always seat itself tightly, and will continue in good condition for a long time. This form is in use at Teplitz, and it has never leaked any appreciable amount.

A proof of the absence of leakage at the auxiliary-valve, or elsewhere, is the fact that it is impossible to draw much of the gas from the chamber into the furnace by merely shutting-off the gas-valve, and then waiting a certain length of time before reversing. In the absence of some opening to admit the air behind it, only so much of the gas will pass into the furnace as is forced out by the expansion due to the greater heat of the chamber. Moreover, should any leakage occur, it would have to be very considerable to do any harm. A slight amount of air mixed with producer-gas does not make it either explosive or combustible, and any small amount of flame, produced directly in front of the leak, would be extinguished by the gas itself.

Another objection which has been urged against the process is the fact that cold air is admitted to the gas-chamber, thus absorbing an undue amount of heat, which is lost when the furnace is reversed and this air passes out into the stack. The air does carry out a greater amount of heat than the gas does under present practice, but calculation shows that the loss from this cause is very small, as compared to the saving by burning the gas effectively. This is also shown by the fact that careful tests of the fuel-consumption of furnaces run for a certain length of time with the Kurzwernhart process and for the same length of time without it, other conditions being kept as similar as possible, have shown that the coal saved was 8.5 per cent. greater, by actual weight, than that which, by calculation, was to have been expected.

Although there is no danger of explosion in using air to sweep the gas into the furnace, when ordinary care is used, it can be made absolutely impossible by a modification of the process in which the products of combustion are used for this purpose instead of air. In this case, a reservoir is provided of sufficient capacity to hold a little more than enough of these products to replace the gas in the chamber and flues. This reservoir may be built either of plates above ground, or of brick-work under ground, according to preference or convenience. During the ordinary running of the furnace, there is open communication between the smoke-flue, reservoir and chimney, which is so regulated by damper that the reservoir is kept full at all times. At the time of reversing, the main gas-valve is shut, and also the connections between the reservoir, smoke-flue and chimney. A valve, placed between the reservoir and the gas-flue, as close to the reversing-valve as possible, is then opened, and also one between the reservoir and the outer air. The air rushes into the reservoir and forces the products of combustion ahead of it into the flues and chamber, thus sweeping the gas into the furnace. As soon as all of the gas is burned, the connections between the reservoir, gas-flue and the air are closed, those between the reservoir, smoke-flue and chimney are opened, the furnace is reversed, and the main gas-flue is opened.

It will be seen, at once, that the only difference between this method, and the use of gas direct, is the substitution of a thick, extraneously produced, separating layer of products of combustion between the air and the gas for the comparatively thin layer, naturally produced *in situ.* The advantages of this use of the products of combustion, instead of air direct, are,—that explosion is made absolutely impossible, that all trouble from a possible leak in the auxiliary air-valve is prevented, and that less heat is lost when the products of combustion pass back out of the chamber into the smoke-flue, since the temperature of these gases, when they enter the chamber, is considerably higher than that of the outside air. As already stated, however, there is, under proper conditions, no danger of explosion when using air direct; there is no leakage of air through the auxiliary valve, when it is properly made; and the loss entailed by the use of cold air as a pushing-agent is hardly worth considering. On the other hand, the smoke-process involves a more complicated apparatus, and requires more floor-space.

The apparatus for either variety of the process can be applied to any existing form of reversing-valve. A detailed description of many of the applications of the air-process has already been published,[2] but the general principles can be sufficiently shown by means of the application to the Forter and to the Siemens reversing-valve. While with proper arrangements the main gas-valve can be used to shut off the gas during reversing, if it be preferred, or if conditions require it; yet there are some reasons which may make it seem desirable not to use the valve for this purpose; for instance, the great weight of the larger sizes, and the natural desire to avoid risking a disturbance in the relation of the gas-valve to the air-valve, when once established. In such a case, a simple form of shut-off valve can be added, to be used only at the time of reversing. The question as to which method is to be followed is one of personal preference or economy, except in those cases in which there is no room to introduce the supplemental gas-valve. Fig. 2 shows a very convenient, cheap, effective and durable form of this supplemental gas-valve.

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[2] *Stahl und Eisen,* Aug. 15, 1904.

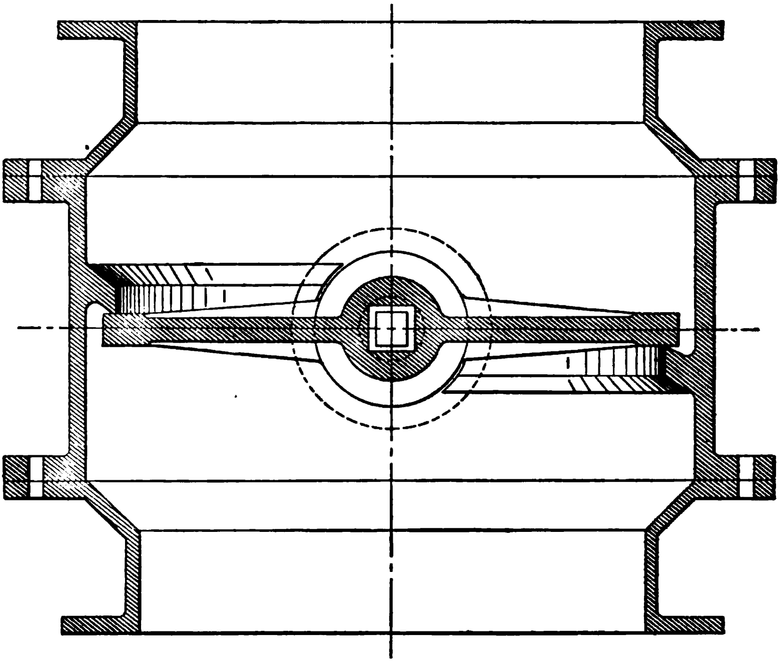

Fig. 2.—Supplemental Gas Valve.

Fig. 3 shows a very convenient arrangement for the Kurzwernhart air-process, with supplemental gas-valve, as applied to the Siemens, or similar, reversing-valve. The counterweighted lever, *a*, is keyed fast to the journal on which the diaphragm of the supplemental gas-valve is fastened. The chain wheels, *R*, and *T*, which are cast in one piece, turn freely on this journal. The wheel, *T*, has a pin, *b*, projecting from it,

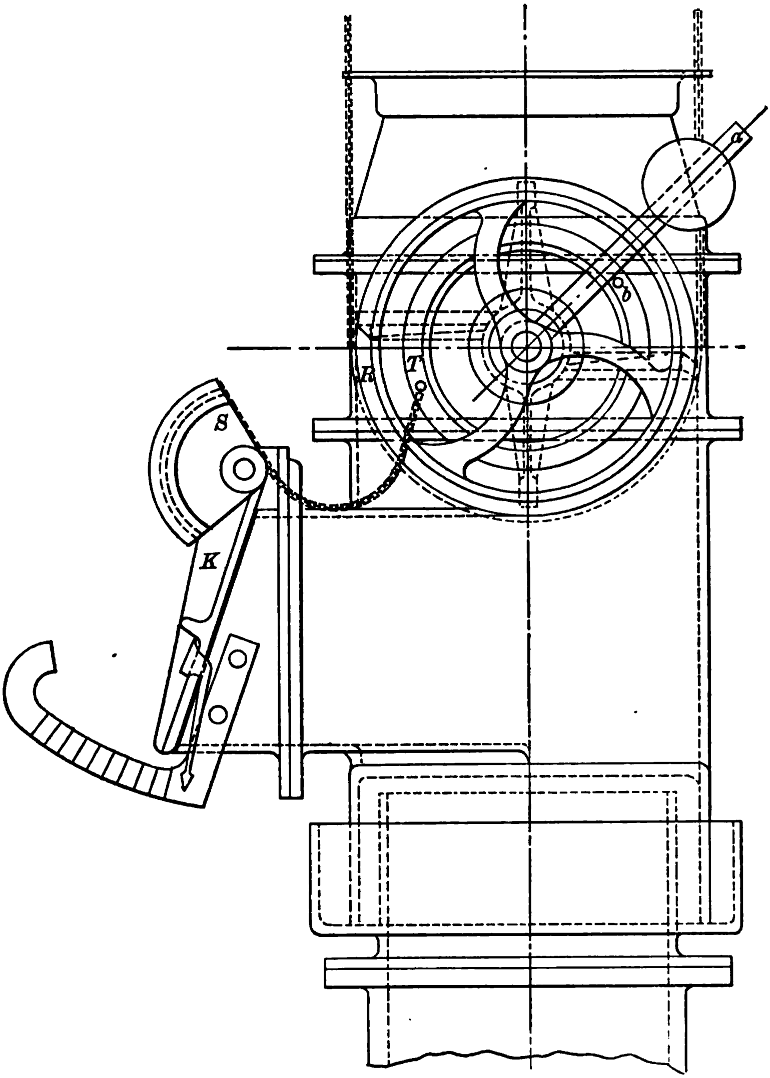

FIG. 3.—KURZWERNHART ARRANGEMENT FOR SIEMENS REVERSING-VALVE.

which engages under the lever, *a*. A chain is also fastened to it, which leads to the quadrant, *S*, on the journal of the auxiliary air-valve, *K*. Another chain passes around the wheel, *R*, and also over a sprocket hand-wheel on the platform, near the lever of the reversing-valve. The supplemental gas-valve is shown in the full open position.

At the time of reversing, the hand-wheel on the platform is turned to the right, and is followed by the wheel, *R*. The lever, *a*, follows the pin, *b*, downwards, and thus closes the gas-valve tightly by means of the counter-weight. In the meantime, the slack of the chain has been taken up on the wheel, *T*, and, by continuing the motion of the hand-wheel in the same direction, the flap-valve, *K*, is opened as far as is desired. When all the gas has been burned in the furnace, the hand-wheel is turned back to the left until the air-valve, *K*, is closed. The furnace is then reversed, and the hand-wheel is turned back to its original position, thus fully opening the gas-valve. This point is fixed by a stop for the hand-wheel or lever. There must be sufficient slack in the chain leading to the air-valve to prevent the latter from opening until the gas-valve is tightly shut. The whole arrangement is simple, cheap and effective, and has successfully met all the conditions of practice.

An arrangement, to be used with the Forter valve, is shown in Fig. 4, in which the main gas-valve is also used as a shut-off valve during reversing. The stem of the gas-valve passes through the nut, *a*, which slides up and down in the frame, *B*. The opening of the gas-valve is adjusted by screw and hand-wheel, in the usual way. From the nut, *a*, projects the pin, *b*, which engages in the cam-slot of the double quadrant, *A*. Lost motion is provided for at *C*, so that the valve may be shut by means of the quadrant, no matter what may be its opening. From each end of the quadrant a chain leads to the corresponding door in the Forter valve-casing,

As a matter of precaution, the air is always brought into the casing over the hood, so that it will sweep all of the gas before it into the flue. If it were brought in at the other end, it would at once turn down the flue, and thus leave a pocket of dead gas at the other end of the casing, which might possibly form an explosive mixture with the air. There is small danger of this occurring, but the possibility would better be avoided. This principle of avoiding all dead ends or pockets for the gas should be applied in designing any particular arrangement, since unnecessary risk of any kind ought to be avoided. It is, therefore, necessary to use, alternately, the doors at each end.

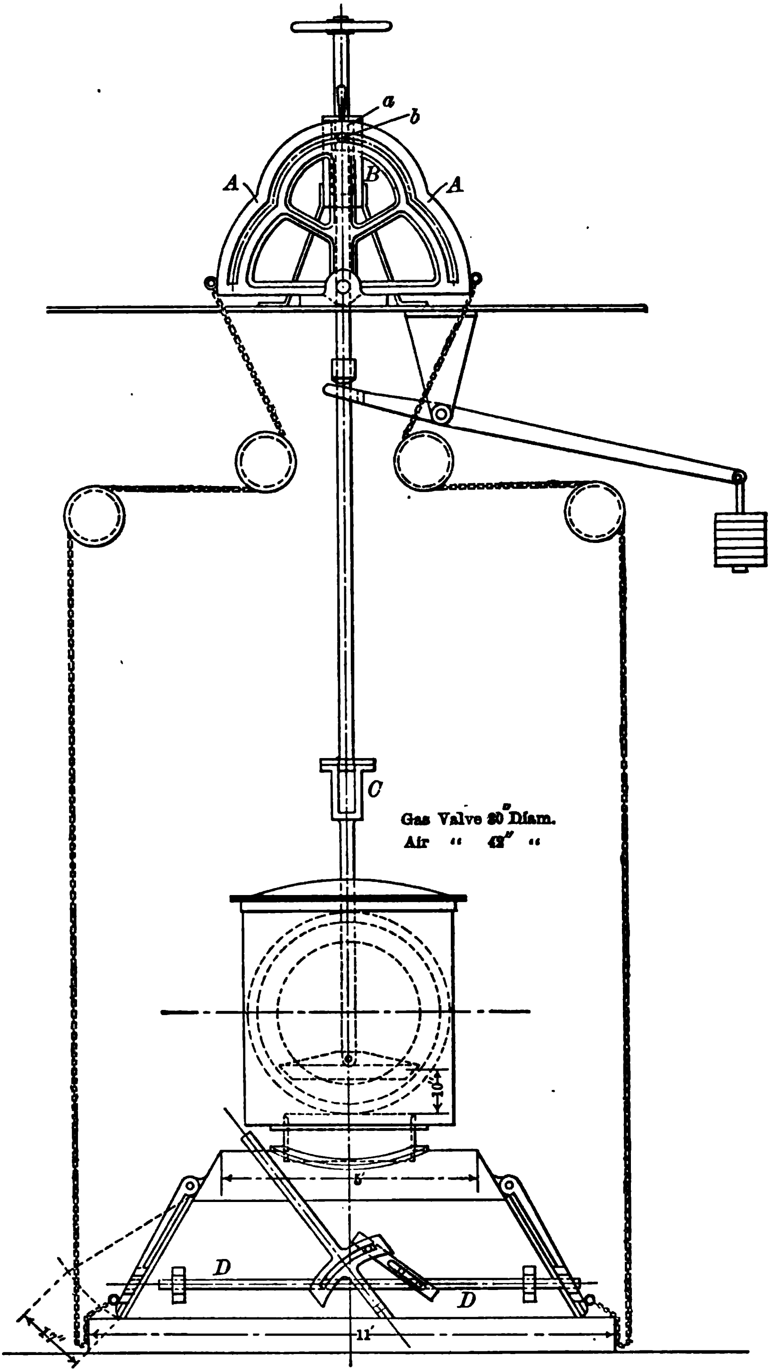

FIG. 4—KURZWERNHART ARRANGEMENT FOR FORTER REVERSING-VALVE.

In order to assure the opening of the proper door, and to prevent the opening of the wrong one, a bolt, *D*, is arranged on the valve-casing, operated by a cam-slot on the reversing-lever, in such a way that the door of the hood-end is free, while that of the down-comer end is locked.

When the furnace is to be reversed, the quadrant, *A*, is turned down towards the locked end of the casing. The pin, *b*, follows the slot of the quadrant, carrying with it the nut, *a*, and the gas-valve. The gas-valve is closed when the pin reaches the bottom of the semicircular part of the slot, which is then on the vertical axis of the valve-stem. The motion of the quadrant is continued in the same direction, and the air-door is opened as far as is desired. A stop should be provided for the quadrant, and the amount of opening can be adjusted by shifting the chain. Enough slack, however, must be provided in the latter to assure the closing of the gas-valve before the air-valve begins to open.

When the gas is all burned, the quadrant is raised until the air-valve is closed. The furnace is then reversed, and the quadrant is raised until the nut is again in its highest position. The main gas-valve is then open, just as it was before reversing, and its adjustment with the air-valve is not disturbed. In the case of large furnaces it will probably be necessary to counterbalance the gas-valve on account of its weight. The weight of the doors on the valve-casing will also have to be adjusted to balance the quadrant.

If it be preferred to use a supplementary gas-valve instead of the main gas-valve, for shutting-off the gas during reversing, it is inserted between the latter and the casing of the reversing-valve. The same quadrant is used, but it has no connection with the stem of the main gas-valve. The nut, *a*, becomes simply a sliding-block, to which a guided rod is fastened. This rod carries a pin, which manipulates the counter-weighted lever, in the same way as does the pin, *b*, in Fig. 3.

If it be desired to use the main gas-valve as a shut-off valve during reversing, in connection with the Siemens, or similar, valve, the arrangement shown in Fig. 4 can be used, but only one-half of the double quadrant is required.

Figs. 5 and 6 show an arrangement for the use of the products of combustion as the direct agent for sweeping the gas into the furnace. In this case, the reservoir is built of brick and placed underground. *A*, *A* is the reservoir; I is the auxiliary gas-valve; *C* and *D* are the valves regulating the products of combustion and the admission of air; and *B* is the damper which controls the flow in the smoke-flue and reservoir,

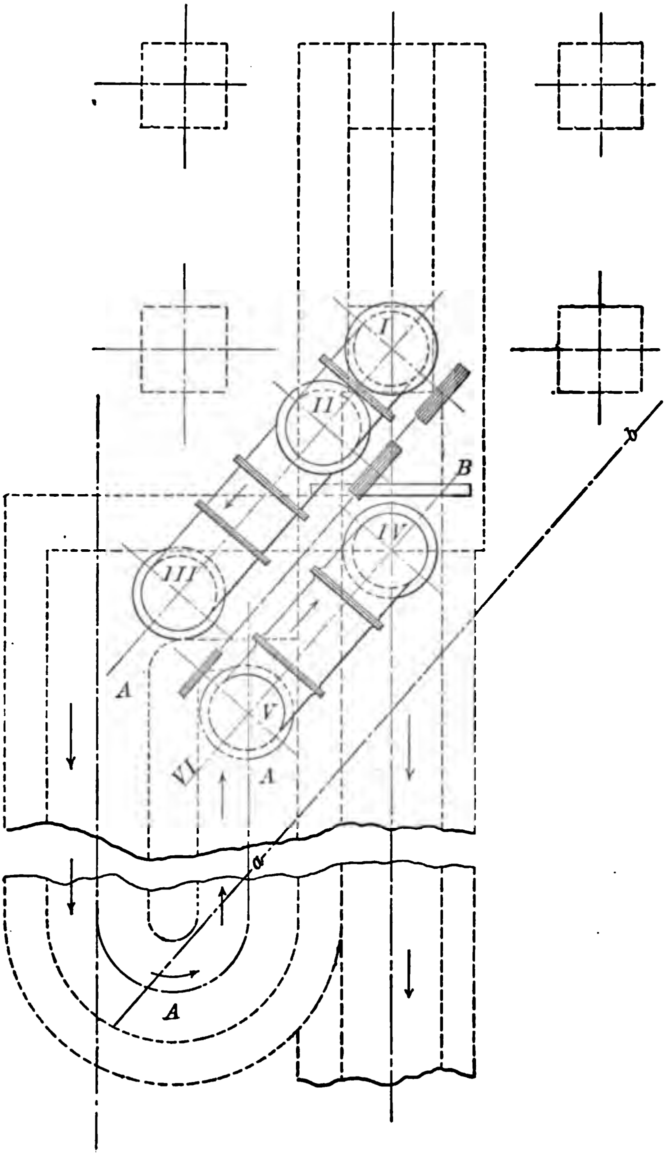

Fig. 5.—Kurzwernhart Arrangement for Smoke Process—Plan.

and which is entirely distinct from the ordinary draft-damper. During the running of the furnace, this damper is so placed as to force enough of the products of combustion through the reservoir to keep it entirely full. At this time the valves, *C* and *D*, are so set that the portion of the products of combustion, which goes through the reservoir, passes up through the opening, II, down III, up V and down IV into the smoke-flue again. When the furnace is to be reversed, I is first shut, and the valves, *C* and *D*, are reversed. This shuts off the connections with the stack-flue at II and IV, and opens that with the outer air at VI and with the reservoir at III. The air flowing in through VI forces the products of combustion from the reservoir up through III and II into the gas-flue, just below the auxiliary gas-valve, I, thus sweeping the gas before it into the furnace. When the gas is all burned, the valves, *C* and *D*, are reversed, thus closing the connections with the stack-flue and the air, and opening those between the stack-flue and the reservoir. The furnace is then reversed, and the auxiliary gas-valve, I, is opened as be-

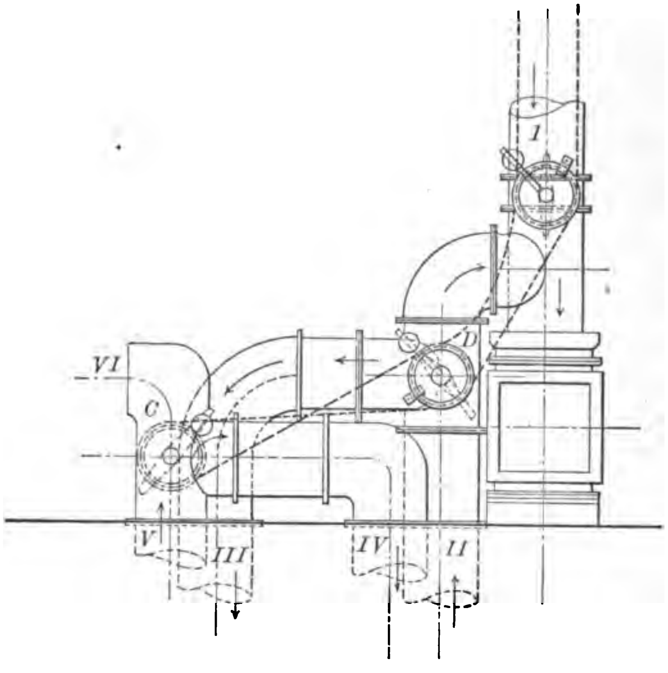

FIG. 6.—KURZWERNHART ARRANGEMENT FOR SMOKE PROCESS—SECTION ON *a–b*.

fore. It will be noticed that all three of the auxiliary valves are operated by a chain from one hand-wheel, and that one continuous motion will throw them all in either direction. Sufficient slack is provided in the chain to insure the shutting of the gas-valve, I, before the valves, *C* and *D*, begin to move.

If a plate-tank above ground be preferred to the underground one, or if the space at disposal require it, the arrangement, as far as the valves are concerned, is precisely similar to that described above, suitable connections being made through tubes. Since the products of combustion in the reservoir are considerably cooler than the gas in the chamber and flues, the former need not be as large as the latter. A reservoir having 60 per per cent. of the cubic contents of the chamber and flues will be amply sufficient.

Although I do not know that this process has been previously described in English, it has received considerable attention and discussion on the Continent. It has been my endeavor to set before you the results obtained from the process, together with all of the objections which have been urged against it, and the answers to them which experience has developed. If it seems to any one that the aggregate saving achieved, though small in detail, is worth making, and that the process deserves investigation, all that I have hoped for has been accomplished.

SUBJECT TO REVISION.

[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

On the Ancient Copper-Mines of Lake Superior.

BY ALVINUS BROWN WOOD, DETROIT, MICH.

(Bethlehem Meeting, February, 1906.)

THE ancient copper-mines of Lake Superior, having been destroyed or covered by modern mining-dumps, are not accessible to the present inhabitants of that region, and, since no more are likely to be found, some account of those already discovered, from one who has seen them, may be acceptable to the Institute.

Early in May, 1855, I took a party of men to open an ancient pit on the Quincy mine-location. Mr. C. C. Douglas was the "Agent," as mine-managers were then called on Lake Superior. The Quincy Co. had previously done work on a fissure-vein, several hundred feet west of the Amygdaloid lode (afterwards called the Pewabic lode), on which was the ancient pit herein described. It was at this pit that the Quincy main shaft was subsequently sunk.

The ancient pit showed an apparent depth of about 4 ft., but when cleaned out it was shown to be 14 ft. deep, having been filled up by the sliding-in of material composed largely of broken rock, taken out in sinking the ancient shaft, and left near its mouth. Midway of the shaft, and below water-level, was found a scaffolding of white-birch poles, which had been used as a landing, to assist in removing the excavated rock. The shaft was 7 ft. in diameter. The excavation had been done by first building fires in order to disintegrate the rock, as was proved by the abundance of charcoal found; then breaking the softened rock with hammers of diorite, such as is found in the greenstone range on Keweenaw point. These hammers had about the size of large paving-stones. Only broken ones were found, the whole ones having been doubtless carried away for other work, such as could be traced on the lode for a hundred feet or more to the south.

At the place where this shaft was sunk, barrel-copper (*i.e.*, copper too coarse to go to the mill, yet not in pieces large enough to be shipped separately) was abundant. This class of copper was most valuable to the old miners; since large masses were too large for them to handle, and stamp-copper was too small to serve their uses. It is evident that they did not understand the art of smelting.

This excavation represents the removal of 41 tons of rock, and the ground at that place, judging from what could be seen in the walls of the shaft, carried fully 12 per cent. of coarse copper. This would represent 5 tons of copper actually extracted. From the amount of ancient work showing further south on the lode, it would not be too liberal to estimate that four times as much more copper, or, say, 25 tons in all, was obtained from this locality. The amount may have been much greater, for the ground under the workings was afterwards proved to be very rich in barrel-copper.

I still have in my possession a handful of fragments of copper, torn from the barrel-copper by blows from the stone hammers, each fragment showing the torn face caused by the blow. These were found in the bottom of the shaft.

At about the same time, Mr. Charles H. Palmer, Agent, and Mr. Wm. B. Frue, his foreman, opened an ancient pit on the Pewabic mine location, where the Pewabic main shaft was afterward sunk. The lode at that place was very rich in barrel-copper for a width of 20 ft. or more. The pit was somewhat irregular, about 6 ft. deep and 15 ft. wide, the length being 20 ft. across the lode, and representing the removal of 138 tons of rock, which carried about 10 per cent. of barrel-copper, or 13.5 tons of metallic copper.

The ancient work extended to the south more than 100 ft., but was not so deep. The ground under these pits proved to be very rich in barrel-copper, as is shown by the workings of the Pewabic Co. (This ground now belongs to the Quincy Co.) I think it safe to estimate the copper taken from this south working by the ancients to be twice that taken from the shaft, or a total of 40.5 tons—probably a great deal more. In the bottom of this shaft were found the remains of a large fire, the unconsumed brands of which had not been moved, indicating a sudden stoppage of the work. One brand, a part of a young black-oak tree, 6 in. in diameter, showed, by the form of the cutting, that it had been cut at the stump while standing. Having been continuously under water, it was well preserved and of full form. It had evidently been hewed with a thin-edged tool, about 2 in. wide. A thin chip, which had been cut from the face left by a previous chip, was broken off at the base, about ⅛ in. thick; but the cutting-tool had gone down 0.25 in. below the upper end of the remaining stub, leaving a gash into which I inserted my knife-blade. This proved that the cutting had been done by a thin, sharp blade, probably of copper, and not by a stone axe.

On the Franklin location, further north, the surface material was deeper, and no ancient work was found.

The ancient miners worked only where the "wash" covering the cropping of lodes or veins was thin, and the lodes were easily found.

Next to the north is the Mesnard mine location. No rich ground was found there, such as the ancients would mine. But near the south boundary, about 200 ft. west of the line of the Pewabic lode, was found a large, broad ancient pit that did not reach bedrock. Around it a cart-load of broken stone hammers might have been gathered, some weighing as much as 20 lb.; none but broken ones remained, the sound ones having been taken away, doubtless for other work. When I discovered the pit, I thought I had made a discovery of value, but the work done showed its true character.

These hammers had doubtless been used to work up a mass of float-copper of several tons weight, similar to the Worminghaus mass found on the Mesnard location, about 1,000 ft. to the northeast, and east of the Pewabic lode. This mass was rocky, and could have been broken up with stone hammers; its weight was about 15 tons, as I remember. It had escaped the notice of the ancient miners.

On the south side of Portage lake, the Isle Royale lode had been extensively worked on the Isle Royale location, by the ancient miners. The Isle Royale shaft was sunk on the main old workings. I did not see this ancient work, since it was covered with waste dumps from the mine when I first visited the mines, in 1854.

At the Huron mine, next south on the Isle Royale lode, the first four shafts were started in 1854, in ground not suited to the ancient miners. In 1856 I took charge of the property, as agent, and pursued work in the first shafts. In 1857 I discovered signs of ancient workings to the south; but in this work, instead of digging pits, the lode had been stripped from north to south. The large stones had been piled up, and the dirt thrown back as the work progressed.

I caused the lode to be cleaned off, beginning at the north end of the old work, for a length of 30 ft. and a width of 16 ft. To the south there were abundant signs of ancient work for an additional distance of 80 ft. About 3 ft. in depth of the lode had been removed where it was uncovered. This surface had had the benefit of disintegration since the Ice Age.

To get an idea of the amount of copper which the ancients obtained, I had the uncovered surface—30 by 16 ft.—worked over with pick and bar, no powder being used. Ten tons of barrel-copper were taken up; the largest piece weighing 1,500 lb. The copper obtained was weighed and shipped to the copper smelting-works at Detroit. I would estimate that the ancients got twice as much as we did, or 20 tons, to say nothing of what they took from the additional ground worked by them to the south.

In the deepest part of this old work, in a pit about 1.5 ft. below the general level of the bottom, I found a leather string about 30 in. long, which was strong and in good condition, having lain under water. About 20 in. of it is buckskin, the balance being beaver-skin, wrapped with colored porcupine-quills. This, and a small buckskin bag, found in an ancient pit near Rockland, Ontonagon district, are the only relics of a personal nature ever found in the ancient mines, so far as I am informed.

No signs of graves, or of foundations to structures, have been found. Doubtless the ancient miners visited this region in the summer season only; and probably they came by the Lakes. That they were navigators is shown by their presence on Isle Royale.

North of the Mesnard mine, the first ancient work was found at the Calumet mine—a single pit, sunk on the Calumet conglomerate. It was discovered by Amos Scott, a man whom I knew well. He was employed by Ed. Hulbert, as foreman, on a property east of the Calumet mine, and called, at that time, the Hulbert mine. The copper was abundant where the ancient pit was sunk, but, being of stamp-copper size, it did not suit the old miners' purposes as well as the barrel-copper found at other places; and this accounts, no doubt, for the limited amount of work done there. The discovery of this pit led Hulbert to purchase from the St. Mary's Mineral Land Co. the lands of the Calumet and Hecla mines.

The next place further north, where ancient work led to the discovery of a mine, was at the Cliff mine, near Eagle river, which was famous and profitable in its day. The vein produced mass-copper.

The next mine of value to the east was the Central mine, located upon the discovery of an ancient pit on the vein, in the bottom of which appeared a large mass of copper. This mass had been well pounded, to detach such pieces of copper as could be thus secured; but the main body was too large to be handled by the ancients.

Still further east, the old North West mine, later known as the Pennsylvania and the Delaware mines, was discovered at a very early day through an ancient pit on the fissure-vein, near the greenstone range.

North of this range, and nearly north of the North West mine, a number of ancient pits were found on a small fissure-vein, which carried sheet-copper well suited to the uses of the old miners. These pits were discovered in 1853, and were frequently seen by me while they were being cleaned out. The stone hammers used at this place were mostly encircled by well-marked grooves; whereas, at the other ancient mines described, the stone hammers found were not grooved, and only a few of them had their sharp corners rounded. Several cedar shovels, or scrapers, about 3.5 ft. long, with the blade on one side only, were found in these pits.

Extensive ancient mining was done on the easterly part of Isle Royale, on narrow veins yielding sheet-copper. This form being, as already observed, suited to the needs of the old miners, they did much work on these veins.

About 1872, Mr. A. C. Davis worked, on the island, a property called the Minong, and brought to Detroit a very interesting piece of ancient work—a mass of copper of 4 or 5 tons, taken from the bottom of an ancient trench along a vein. This mass had been deprived of all portions of copper that could be detached by pounding with stone hammers, and the whole surface of the mass had been pounded into deep pits and ridges in attempts to detach other pieces. It showed an immense amount of labor done. Mr. John R. Grout, of the Detroit copper-smelting works, shipped the mass to the Michigan University at Ann Arbor, and offered to sell it to the University at half its cash value, but the Regents did not make the purchase. Perhaps they lacked money; perhaps they lacked appreciation. The mass was shipped back to the smelting-works and went into the furnace. Thus a thing of very great interest was lost. Had the University taken it, it would be the most interesting in all its collections, and of special interest to Michigan.

In the Ontonagon region, extensive ancient mining-work was done at the Minnesota mine, in the fissure-vein, where the historic mass of copper was found below water-level, shored up on timbers, in an ancient shaft, the work having been continued below the mass.

In the Rockland district, extensive work was done on the Amygdaloid lodes, where rich bunches of barrel-copper were found. I was not personally acquainted with these workings.

In 1870 there lived at Gratiot lake, in Keweenaw county, Michigan, a gentleman 70 years of age, of good character and intelligence, who told me that he was in the Ontonagon district at the beginning of mining there, and was conversant with the old miners' work. He said that, at a point on one of the Rockland amygdaloid lodes, where barrel-copper was abundant, an ancient drift had been driven for 40 ft.; at the inner end, in the upper dry corner, a considerable roll of white birch-bark was found; which, on being unrolled, was seen to be covered with what he called "hieroglyphics." He said he saw this roll, and that it "was carried East by a man," and he never heard anything more of it.

The native copper of the Lake Superior mines is accompanied, to a limited extent, with native silver, attached to the surface of the copper, and, at times, enclosed within it, the two being firmly united and each pure, and in no case alloyed. This condition has been considered peculiar to the Lake Superior mines, and as proof that specimens exhibiting it came from Lake Superior. Samples of this kind, found in the ancient mounds of Ohio, have consequently connected the mound-builders with the old miners. The mound-builders, it is thought by historians, migrated south 900 or 1,000 years ago, and were the Toltecs or Aztecs of Mexico, probably the latter. This gives some indication as to the time when the ancient mining-work was done.

The copper they obtained by working the ancient mines, as shown by the part estimates on previous pages, must have amounted to several hundred tons. They also had the first picking of the float-copper, dislodged from the lodes and veins during the Ice Age, which must have amounted to many tons. The present inhabitants have picked up many thousands of pounds. The wonder is that the ancients did not do more mining, since the copper, being so greatly superior to their stone implements, must have been of great value to them. The limited amount of work done by them may indicate that they occupied the country but a short time.

More copper implements have been found in the ancient mound country of Wisconsin than in any other State, as is shown by the collection at the State University at Madison. Illinois, Michigan and Ohio have yielded many specimens of implements. The Field Museum at Chicago has many valuable specimens from these States.

It must be remembered that all the implements thus found were lost treasures of the utmost value to the owners. I have a spear-head, 11 in. long, of very perfect construction, which was taken from a mound on the left bank of the Wisconsin river, just below the Dalles. This may, or may not, have been a burial mound.

All of the older valuable mines of the Portage Lake district, as well as those of the Keweenaw and the Ontonagon districts, were found by means of the ancient workings, which are now destroyed or covered by mine-dumps.

The new mines, opened in the past few years on the south side of Portage lake, were covered too deep by soil and glacial drift to be found by the ancients; and the same may be said of those opened on the Osceola and the Kearsarge lodes on the north side of Portage lake.

Nine years ago I purchased from a curio dealer at Denver a thin circular disk of native copper and silver, nearly one-half silver. The origin or source of the metals from which it is made is evidently the Lake Superior mines. This disk, shown in Fig. 1, is 2.5 by 3.5 in. size; a projection on one side serves for a handle, a hole at the end being doubtless modern. The disk is concave, and on the concave side there is a conventional picture of the face of the sun, outlined by deep creasings with a sharp point. The face is 1.5 in. in diameter, and not quite perfectly round. There are 13 radiating curved lines drawn from the face to the margin, which may represent the 13 lunar months. The lines show on the back as raised lines. The eyes have that straight horizontal appearance to be seen in the ancient carvings on stone, which are exhibited in the Mexican National Museum in the City of Mexico.

I also bought a rude bracelet of the same material, roughly pounded out and bent to spring on to the wrist. It is very irregular in form; from 0.6 to 1.5 in. wide, with very jagged edges. On it, for ornament, are placed four turquoises of excellent quality, but roughly ground into faces. Turquoise, used to ornament a bust carved in stone, is to be seen in the Mexican Museum.

The turquoise is a Mexican stone, not having been mined in United States territory until recently, except at the ancient turquoise mine near Santa Fé, in New Mexico. The stones are set on to the bracelet by cutting four clips in the copper for each stone, and raising these clips, or tags, so as to inclose the stones and keep them in place.

The dealer of whom I bought these articles told me that he bought them in the City of Mexico, from a very large collection of minerals and ancient relics that had been collected by several generations of owners. The owner, at that time not being so interested as his ancestors, was selling off the collection as he had opportunity. The sun disk, being of a peculiar combination of metals, and a religious emblem as well to the old sun-worshipers, would be likely to be handed down through many centuries by the ancient people. The bracelet may have come down with it. It would have been highly prized for its unusual material, and may have been regarded as a sacred thing. The material for both disk and bracelet being of undoubted Lake Superior origin, raises the question of how it got to Mexico in the olden time, and the ready reply is,—that it was probably taken there by the old mound-building miners, the Toltecs or Aztecs, when they migrated to the south. They were probably driven from home by an enemy, for they were in a good country, desirable to live in, in the Lake region.

With the facts given herein, and if the inferences stated are correct, then we have a clear indication as to who did the ancient mining on Lake Superior, and also as to who were the mound-builders, namely, the Toltecs or Aztecs of Central Mexico, probably the latter.

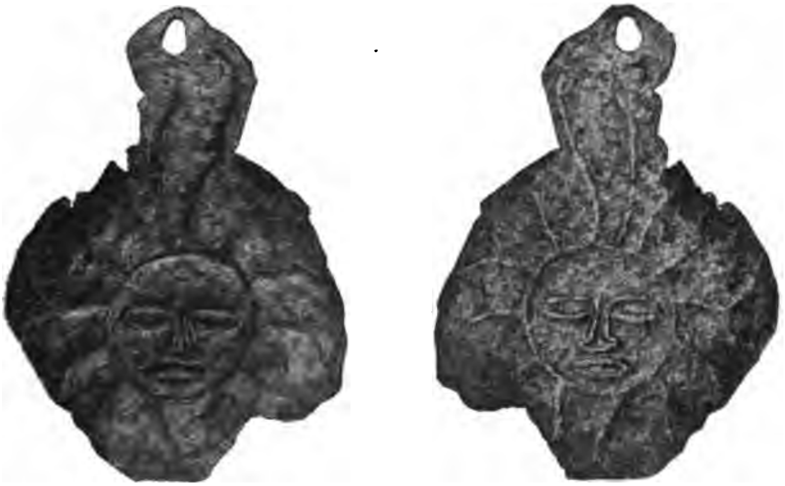

FIG. 1.—SUN-DISK OF NATIVE COPPER AND SILVER.

Fig. 1 is a three-quarter sized photographic view of the sun-disk. The lighter shades represent the silver portion and the darker shades the copper. The back, or convex side, shows most silver.

At the first visit of the old French missionaries to Lake Superior, the Indians knew nothing of the old copper-mines, though they had lumps of float-copper, which they regarded as "Manitou." Nor did the modern Indians know anything of the old mines.

SUBJECT TO REVISION.

[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

The Classification of Coals.

(Bethlehem Meeting, February, 1906.)

A discussion of the paper of Marius R. Campbell, read at the Washington meeting, May, 1905, and published in the *Bi-Monthly Bulletin*, No. 5, for September, 1905, pp. 1033–1052.

DR. PERSIFOR FRAZER, Philadelphia, Pa. (communication to the Secretary):* Mr. Campbell's very interesting contribution, after complimentary mention, finally decides against the acceptance of the classification proposed by me in a paper bearing the same title and read at the Wilkes-Barre meeting, May, 1877.[1] That paper was written primarily for the Second Geological Survey of Pennsylvania, then three years in progress, and chiefly to give definite limitation to the four rather vague classes into which H. D. Rogers had divided the coals of Pennsylvania, which classes were used by Pennsylvania coal producers and coal consumers; namely, anthracite, semi-anthracite, semi-bituminous and bituminous. It was also my aim to point out the futility for classification of taking into account any other characteristics of a coal than those essential to its existence as a fuel, *i.e.*, its combustible constituents. The absurdity of considering "ash" as a factor in classifying a coal was illustrated by an analysis of the Hudson River slates, showing that if the whole rock (of which the volatile hydrocarbons formed only 3 per cent.) were considered as a slaty coal, it would come within H. D. Roger's definition of a "hard dry anthracite" (although a very bony one); whereas, if the combustible matter were first extracted from the inert rock and separately analysed, it would prove to be near the top of the characteristic bituminous coals, with 62.5 per cent. of fixed carbon and 37.5 of volatile hydrocarbons.

In the same paper, I emphasized the importance of separating the water from the volatile combustible matter before attempting the calculation of a fuel ratio and subsequent classification. That this subtraction was not embodied in any of my tables was because there were no data from which to obtain it.

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* Received January 9, 1906.

[1] *Trans.*, vi., 430.

Shortly before 1877, it appeared from interesting experiments in Austria that, even at ordinary pressure and temperature, bituminous coals exposed to the atmosphere suffered rapid and notable losses of their volatile combustible matter.

The attempt to differentiate lignite from bituminous coals through their respective percentages of water would result in contradictions of the same kind: certain exposed coals becoming lignites after a rainy season and bituminous after a drought. Unessential constituents (or impurities) are incommensurable with essential, and are of no more use in defining kinds of coal than weight would be in defining mental images.

Mr. Campbell thinks my proposition for giving definite meanings to the four terms already in use in Pennsylvania, failed as a basis for a general classification of coals (1) in grouping all the coals with a fuel-ratio of 5 or less into a single class.

The same objection might be made to the recognition of the groups of oxides and oxygen salts in Dana's, or of silicates in Albin Weisbach's division of minerals. But the occurrence of a great preponderance of instances of a given phenomenon in a certain restricted part of an accepted scale is not *per se* a reason for discarding the scale for general classification, although it may involve the necessity of a sub-classification for this overcrowded portion.

At the outset of any attempt to arrange objects in systems the purpose of the arrangement must be clearly understood. If it be for practical use in commerce, the refined methods of research will always be inappropriate. On the other hand, if it be desired to create definite species or varieties of the objects, no other than the most delicate methods can be employed. First, then, it is necessary to determine what sort of classification is applicable to a substance like coal.

It is superfluous to say that coal is seldom, if ever, a definite mineral, but usually such a mixture of substances as used to incense that prince of determinative mineralogists, Herr Wappler, the late chief of the mineral salesroom of the Mining Academy in Freiberg, Saxony. When such a mixture was brought to him as a mineral with a new name, he would utter in a tone of repugnance the single word, *Zeug!* (stuff!).

If coals be variable mixtures of combustible and incombustible materials, valuable only for their content of the former, the application of methods of ultimate research for classifying them is not less useless, and much more difficult, than the determination of the mineral species of stones used for ballast. Whatever method be used should exclude all properties but those which are essential to the material as coal; and, since there can be no possibility of the absolute individuality of a substance which results from ever-changing conditions of formation, the only essential character which can be utilized for classification of coal would seem to be that of its combustible components. Hence, not only does a fuel-value of some kind offer the best means of classifying coals, but any analysis, even though partial or "proximate," which gives each class a distinctive value, should suffice for the purpose.

Since we are dealing with variable mixtures, incapable of classification in a strictly scientific sense as species or varieties, what is needed is a ready means of distinguishing differences by the eye and touch, aided in certain cases by a few of the most elementary tests to ascertain the specific gravity, friability, manner of burning, method of coking, volume of water-vapor, of hydrocarbons, etc.

Mr. Campbell, speaking of my effort to define the scheme already proposed by H. D. Rogers and universally adopted in Pennsylvania (and, so far as I know, thoughout the United States), says: "The selection of the name 'semi-bituminous' was unfortunate." I perfectly agree with him; but this was not my selection. The chief of the First Geological Survey of Pennsylvania introduced the term, and in trying to co-ordinate it with the three others which he had adopted, created classes which overlapped each other.

I repeat that my answer to Mr. Campbell's first objection to the proximate-analysis-fuel-ratio system (*i. e.*, that it groups a largely preponderant number of bituminous coals in the class 5 to 0, while the less numerous classes range from 100 to 5) is, that the objection is not valid as against a classification, though additional means for differentiating the members of the over-crowded class are required. The classification was intended principally for Pennsylvania, though applicable elsewhere.

To his second and last objection, that no provision is made for lignite in my scheme, I reply that none is needed, even if it were possible (as it is not) to separate lignite from bituminous coal. There is an insensible gradation from lignite through brown-coal to bituminous, and thence through all manner of variations ultimately to hard dry anthracite and graphite; and no single division has any greater value than one of the arbitrary divisions of the rays of the spectrum designated by the name of a special color. It may be doubted whether the reasons are well founded which have led Mr. Campbell to conclude that my system, and several of his own, are inadequate; though it must be conceded that the classification in Table VI. has at least one advantage over all the others, which is mentioned below; its vulnerable point being the inclusion of "hydrogen in the water."

Beginning with Table I. of his paper, in which he has applied my system to the Government collection of 56 coals from various parts of the United States, he remarks that in the upper part of the column (where the quotients of the fixed carbon, divided by the volatile hydrocarbon, represent large numbers) the differentiation of anthracite from semi-bituminous is sharp, but in the lower part of the column (where these quotients are smaller numbers) there is great confusion,—two samples of Pittsburg coal standing 24 and 36 in the list. The two quotients or fuel-ratios referred to are 1.49 and 1.25 respectively, and the interval between them is only 0.12 per cent., yet within this compass 12 coals have been placed with an average consecutive difference of but one hundredth of 1 per cent.! Quantities as trivial as this might easily occur from casual variations in the vegetation from which the coal was formed, so trifling that no dissimilarity from the adjoining coal could be noted; or from the unavoidable error which must accompany even the most careful sampling; or from physical and chemical changes in the coal in the intervals between two analyses. To such refinements in separation no method of classification is adapted.

On purely theoretical grounds, the ratio between $\frac{C + C'}{H}$ can lead to no more accurate results than that of $\frac{C}{HC'}$ (C′, representing the carbon in combination with hydrogen, C, the uncombined or "fixed" carbon, and H, the hydrogen in the hydrocarbon). Any of the sources of error just alluded to will vitiate the natural sequence obtained by analysis in one expression as much as in the other. The ratio between a dividend and a divisor will not be made more constant or valuable by splitting the divisor into two factors, one of which becomes the new divisor, while the other is added to the old dividend for a new dividend.

Mr. Campbell is of the opinion that in Table VI., where the total carbon (*i.e.*, the fixed carbon plus that combined with the hydrogen in the volatile combustible matter) is divided by the hydrogen in the volatile combustible as well as that in the water, an almost ideal classification is obtained. The formula becomes $\frac{C + C'}{H + H'}$, (H′ being the hydrogen in the water).

The amounts of water retained by different samples of the same air-dried coal will depend upon variations in physical condition not always possible to ascertain; and the greater weight of hydrogen in any such sample, obtained by adding to its combustible hydrogen that combined in its mechanically entangled water, must necessarily lower its quotient or fuel-ratio, and thus separate it from other samples with which, but for this hygroscopic characteristic, it would be closely associated. The recognition of occluded water as a factor at all in estimating the fuel-ratio, is an abandonment of the principle of confining the definition to the essential (*i.e.*, the combustible) characteristics of the coal. For although it is very probable that the water vapor is dissociated, and that both of its constituents enter into combinations during the combustion of the coal, yet the loss of calorific effect involved in these reactions, through the expenditure of energy in overcoming specific and latent heat and chemical affinity, must exclude it from consideration as a fuel.

Mr. Campbell does not say definitely, in his explanation of Table VI., that the hydrogen in the water has been used in calculating the carbon-hydrogen ratio; but in two or three calculations his results are obtained by dividing the total hydrogen of Table IV. into the total carbon of Table V.

However, this assumption is not always exactly verified. Thus, for "West Va., No. 1," of which the total hydrogen-value (Table IV.) is 5.67, and the total-carbon percentage

(Table V.) 84.45, Mr. Campbell's ratio in Table VI. is 14.7, whereas, apparently, it should be 14.89 (or 14.9).

If any criticism can be made of these valuable tables, it is that their purport is not stated with sufficient fullness in the text or title.

Without pretending to exhaust all the extremely interesting aspects which an examination of them reveals, it occurs at once that the main reason why the divisions in Table VI. are more satisfactory than the others is because the divisors (the weights of hydrogen in the volatile combustible matter and in the hygroscopic water) being smaller numbers, and the dividends (the weights of the fixed carbon with those of the hydrocarbons added) larger, the quotients, and therefore the figures representing the gradations, are also larger, and will accommodate more members of a series.

For instance, the carbon-hydrogen ratio of the brown lignite, "Texas, No. 1" (9.4), at the bottom of his scale, is less than one integer smaller than the carbon-hydrocarbon ratio for anthracite, Penna., No. 3 (10.22), at the very top of my scale of classification.

Mr. Campbell's system has also a manifest advantage over mine in dealing with the highly bituminous coals and lignites containing little or no uncombined carbon; for he still obtains a measurable ratio by splitting up the compound (of which the weight was my divisor, with nothing to divide) and making its heavy component, carbon, the dividend—thus getting a whole number for his quotient.

While congratulating Mr. Campbell on the painstaking work which has made his ingenious improvement on the fuel-ratio system possible, and sharing with him both the hope and the belief that future and more extensive investigation will lead to still further improvements and increase its value, I doubt whether the twelve groups indicated in Table VII. will ever be firmly established, or would assist either the scientific or the practical man if they were.

Nor does it seem advisable to call the determination of two out of a number of elements always present in coals an "ultimate analysis." In fact, such a determination is not much less "proximate" than the method employed by the Second Geological Survey of Pennsylvania, *et al.* It may well be that other factors than carbon and hydrogen will some day furnish the means of a further differentiation of lignites, brown coals, peats, and cannel coals.

In following the figures of Mr. Campbell's six tables, along the same line from one table to another, it is very interesting to note how curiously the changes of sequence follow the changes of basis of classification. As these tables are spread out over eleven pages in his paper, I have combined them in six parallel columns on one page, for better comparison.

In the symbols at the head of the columns, C represents uncombined (or fixed) carbon; C′, carbon combined with hydrogen; H, hydrogen combined in the volatile hydrocarbons; and H′, that in the water. The calorific value is in British thermal units. The numbers in the left-hand column are those given by Mr. Campbell to the 56 coals from various States, which formed the material for his experiment, in the order in which they arranged themselves by my classification of fuel-ratio. They begin with the hard anthracite and end with a Texas brown lignite, the first and highest fuel-ratio (No. 1) being 10.22, and the last and lowest (No. 56), 0.68.

The coals in the other columns are designated by their places in the first or left-hand column, so that the extent of their displacement by reason of another system of classification is at once seen.

In all the tables the values decrease in descending, except in Table IV. (hydrogen), where, of course, they increase in their passage from anthracite to bituminous.

There is a fair agreement of data in Tables I., II., IV., V., and VI. in the upper parts, but not in Table III., whence we learn the useful lesson of the great calorific power of the Pocahontas coals, which fill the first three places at the head of this column; which also contains, among its first seventeen numbers, all of the twelve West Virginia coals examined.

TABLE I.—*Comparison of Sequences in Tables I. to VI., inclusive, of Marius R. Campbell's Classification of Coals.*

I.	II.	III.	IV.	V.	VI.
$\frac{C}{HC'}$.	C.	Calorific Value.	H + H′.	C + C′.	$\frac{C + C'}{H + H'}$.
1	1	6	1	1	1
2	2	5	2	6	2
3	3	4	4	5	4
4	4	10	3	3	3
5	5	8	7	2	5
6	6	15	8	4	7
7	7	9	9	10	9
8	8	11	5	7	8
9	9	12	6	8	6
10	10	3	10	9	10
11	11	13	11	15	11
12	12	7	13	11	13
13	15	14	12	13	15
14	13	16	20	14	12
15	14	2	15	16	14
16	16	24	14	12	16
17	18	36	32	24	24
18	19	21	16	18	21
19	21	1	24	36	32
20	20	19	17	23	19
21	24	18	21	19	20
22	17	30	33	21	18
23	23	23	19	22	36
24	22	32	30	32	30
25	30	22	36	34	33
26	27	53	18	30	22
27	25	20	27	53	23
28	26	34	41	42	17
29	36	27	25	33	27
30	32	33	51	20	25
31	33	42	22	27	30
32	34	38	26	25	34
33	35	35	39	54	42
34	29	17	49	38	38
35	42	25	23	17	35
36	38	44	55	44	53
37	41	54	35	35	44
38	31	43	38	43	26
39	28	52	28	41	43
40	37	48	52	48	54
41	43	37	40	52	48
42	39	41	48	26	52
43	52	26	31	37	37
44	48	29	37	46	28
45	45	46	44	45	46
46	53	45	43	29	39
47	47	47	42	47	45
48	46	28	46	28	29
49	44	31	54	31	31
50	54	39	47	39	47
51	40	40	34	40	51
52	51	55	45	51	40
53	49	56	29	56	55
54	50	51	50	50	49
55	55	50	53	55	50
56	56	49	56	49	56

SUBJECT TO REVISION.

[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

Biographical Notice of George H. Eldridge.

BY S. F. EMMONS, WASHINGTON, D.C.

(Bethlehem Meeting, February, 1906.)

By far the greater number of the members of this Institute are men who are engaged in the strenuous work of the technical part of their profession, and find little time for the abstract scientific work which is less distinctly practical and pecuniarily remunerative. There is, however, a small but increasingly numerous class whose members devote themselves to broad geological problems which underlie the systematic development, and whose work, theoretically, ought to precede and form a basis of that of their more practical brethren. These are the so-called mining or economic geologists, who are, for the most part, connected with State or National geological surveys. From the character of their work, the life of these men necessarily follows rather different lines than that of most of their colleagues, and is not generally familiar to them. It seems admissible, therefore, that to the life of a prominent member of this class, who died during the past year, having literally sacrified his life to his work, a more extended notice should be given than the relatively small number of his contributions to the *Transactions* might seem to justify.

George Homans Eldridge, son of Ellery and Sarah (Mathews) Eldridge, was born on Cape Cod at Yarmouth, Mass., Christmas day, 1854. His boyhood education in the public school at Yarmouth was followed by a six years' course in the Public Latin School at Boston, from which he entered Harvard University in 1872, being graduated with the highest rank in his class in the natural sciences in 1876.

During his college course he spent the summers of 1875–6 at Cumberland Gap, Ky., as volunteer aid to Prof. N. S. Shaler, who was then in charge of the State Geological Survey of Kentucky. This vacation work, undertaken by him rather as a pastime, gave him his first leaning toward geology. Soon after graduation, through the failure of one of the trustees, his father's estate became so impaired that he found himself obliged to give up his chosen profession of medicine, and to embrace the more immediately remunerative one of teaching, in order to meet the responsibilities thus early thrust upon him. To this work he devoted himself with such assiduity and success that he was early appointed principal of the high school at Nahant, Mass. His was, however, too energetic a nature to allow itself to be tied down to the routine of a simple pedagogue. He organized a series of lectures on the natural sciences for the little community in which he lived, and still found time to take private lessons on the practical side of geological work from his former inspiring teacher, Prof. Shaler of Harvard.

It was early in 1879, while still in charge of this school, that the opportunity presented itself which ultimately lead to the adoption of his life work, that of economic geologist on the United States Geological Survey. It was in this year that that institution was created as a permanent branch of the government service to succeed all previous and temporary organizations of its kind. During the same year, Gen. F. A. Walker had been placed in charge of the Tenth Census of the United States, with unusually wide powers and large appropriations. It was his broad conception that the census work should be something more than a mere compilation of dry figures. He thought it should also include such a critical study of the principal branches of industry of the country as would serve to guide Congress in its economic legislation during the following decade. To accomplish this, he placed the investigation of the different industries in charge of the men best fitted for the respective work, under whom the personal investigations should be made by experts chosen for their special qualification. In pursuance of this plan, the Director of the new Geological Survey was given charge of the investigation of the precious metals, and to Prof. Raphael Pumpelly was entrusted that of the other useful metals, principal among which, at that time, were iron and steel.

Among the first special experts engaged by Prof. Pumpelly for the active part of this work was Eldridge, whose fitness for this new and peculiarly difficult work had been testified to by

Prof. Shaler, from his intimate knowledge of the qualities of the man gained during the vacation work under him in Kentucky. Special branches of investigation to which he was assigned were the base-metal deposits of the southern Appalachians and the coal-fields of northern Montana, which, up to that time, were practically unexplored.

Two years later Prof. Pumpelly took charge of the Northern Transcontinental Survey, which had been organized by Henry Villard, then President of the Northern Pacific railroad, for the purpose of making a study of the mineral resources of the region traversed by that road. Eldridge was one of the first geologists employed by him, and was given charge of the Rocky Mountain division, to which was entrusted the solution of some of the most difficult and critical problems involved. Some of the results of this work are found in the *Reports of the Tenth Census* (volume xiii.); but, owing to its sudden termination, the results of the Northern Transcontinental Survey were never fully published.

When, in the winter of 1883–4, financial disaster overtook the Northern Pacific railroad, and the Northern Transcontinental Survey was, in consequence, suddenly disbanded, of the geologists thus set free, Eldridge, on the recommendation of his former chief, Prof. Pumpelly, was the first to be transferred to the United States Geological Survey, to fill a vacancy then existing in its corps of economic geologists.

From 1884 to 1890 Eldridge was attached to the division of mining geology, under my direction, and his work during this time lay mainly in Colorado. Eldridge early distinguished himself for his keen insight into stratigraphic problems, especially those connected with the underground development of coal-seams. Among his fellows his most striking characteristics were his untiring energy and the thoroughness with which he mastered every detail of his subject. His physical endurance was phenomenal. In camp-life in the mountains, where, at that time, the physical difficulties to be overcome were greater than at the present day, he seemed to gather new energy from every obstacle that came in his way; and while always cheerful, he became eminently so where others, through an accumulation of difficulties, were inclined to be discouraged. Winter work in these elevated regions had hitherto been considered inadvisable, but Eldridge demonstrated for the first time that such work was practicable by remaining in camp sometimes through the entire winter. During these years he was mainly occupied with stratigraphic problems connected with the southern Elk Mountains in Gunnison county, Colo., and with the Denver Basin on the eastern foot-hills of the Rocky Mountains. In each case the completion of the work was unavoidably delayed by the inability of the topographic force of the Survey to finish the necessary maps, and Eldridge was called upon to do no inconsiderable part of the topography himself, he being eminently possessed of the topographic skill which forms so important a part of an American geologist's training.

Many other geological investigations in the Rocky Mountains were carried on by him during these years, for which he received no public credit, the results having been either not yet published or else incorporated into the work of other geologists.

In 1889, in addition to other work on which he was engaged, Eldridge was called upon by the Director to compile a record of the artesian wells of the United States, and to map the distribution of coal in the arid region. In the then-existing state of knowledge, either of these pieces of work involved an amount of research that few would have been willing to undertake to complete in any limited period; but Eldridge, with his usual energy and cheerfulness, undertook both, and soon delivered to the Director maps showing, respectively, the distribution of coal-developments in the arid region, and the location of artesian wells throughout the United States, with an article on those of the entire world. There seems to be no record of the printing of these reports, but they may be safely assumed to have been the starting-point for the elaborate investigations on these subjects now conducted by special departments of the Survey.

In 1890, while putting some finishing touches on his Denver Basin work, much of which was dependent for its data upon the records of artesian wells, he made his well-known study of the Florence oil-field,[1] which was the first scientific investigation of commercially successful oil-production in the Rocky Mountain region, and a work that has had a most favorable influence upon an industry that has since assumed great importance in the West.

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[1] *Trans.*, xx., 442–462 (1891).

In the decade commencing with 1880, the economic work of the United States Geological Survey was first extended to special investigations of the individual useful minerals, and in the pioneer work of this branch, as of many others, Eldridge took a leading part.

Unusually rich phosphate rock had recently been discovered in Florida in hitherto unknown geological relations, and a Florida division was created, of which Mr. Eldridge was put in charge. The investigation was particularly difficult, because the country rises but little above tide-level, and no natural sections can be found; hence, the geologist must depend upon artificial excavations for his data. The region, moreover, is unhealthy during the great heats of summer; consequently, the work was mainly carried on during the winter and spring months, and Eldridge continued to give up his summers to work in the Rocky Mountains; thus, he accumulated double the amount of field data, and had correspondingly smaller amount of time than his fellow-geologists for working up his material in the office. For a long time, moreover, accurate maps of the region were entirely wanting, and, while waiting for these, Eldridge was frequently assigned to work in other fields, which momentarily seemed of more pressing importance; thus, those not cognizant of the facts may have been led to blame him for delays, whereas, in point of fact, he was for a long period only able to devote to this work, which he had so much at heart, odd moments stolen, as it were, during intervals of other work.

In 1893 he published[2] a preliminary sketch of the geology of the Florida phosphates. During the following years, however, he was unable to give any time to this work, being called upon to take charge of a new type of Survey work in the West. This was the rapid geological reconnaissance of hitherto unexplored areas of the Rocky Mountains, destined to fill up gaps in the geological map of the United States on the 40-mile scale, in course of preparation by the Survey. Mr. Eldridge was eminently endowed with the qualifications for such work, namely, energy in exploration and a field-experience that enabled him to grasp rapidly the salient features of the geology of a region. During the summers of '93, '94, he made such surveys of large areas in northwestern Wyoming and in northeastern Idaho, respectively, and in each case had worked up his material, and had his report ready for the printer, before the opening of the succeding field-season.

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[2] *Trans.*, xxi., 196–231 (1902–3).

In the summer of 1895 he was assigned to the investigation of the mineral resources of the Uncompahgre and Uinta Indian reservations, in Utah, a knowledge of which had become of importance to the government, because of the demand for the throwing open of these lands to public occupation. In that summer's work he investigated, alone and unaided, 7,000 sq. miles of very difficult country, and, as a result of his work, prepared in the following winter a report[3] on the most important mineral resources of that area—the Uintaite-deposits—which constituted at that time the most comprehensive discussion of such deposits, not only for this region, but for the whole continent.

Immediately upon completion of this work, in the spring of 1896, his Florida phosphate work was taken up again, and carried on continuously until interrupted in the following year by a special order of the Secretary of the Interior, that he make an investigation of the asphalts of Utah, which should furnish data for the Land Office in regard to the best methods of opening up the Indian lands for mineral occupation. His report on this work, being for the private use of the Department, has never been published.

When the discoveries of gold in Alaska had assumed considerable industrial importance, Congress, by its Act of January 28, 1898, ordered special geological and topograpical surveys to be made of that region, appropriating $20,000 for the purpose. This constituted an entirely new branch of work for the Survey, and required a novel and special organization of parties and methods of transportation, which could not be governed to advantage at a distance of 6,000 miles from the field of work, but necessitated a responsible head, who could direct the work on the spot. The qualifications for such a position were administrative capacity and tact, combined with geological experience and great physical endurance. Eldridge, being judged to be the one who best combined all these varied qualities, was appointed geologist in charge of this work in February, 1898. He at once took charge of the outfitting and preparation of the various parties, which sailed from Seattle on the United States gunboat *Wheeling* on April 5th. He had characteristically chosen for himself what promised to be the most difficult piece of work, namely, the exploration of the highly mountainous interior of the main peninsula. On May 4th, with Mr. Robert Muldrow and several camp assistants, he started up the Sushitna river, following it to its head, and then crossed the divide on foot to the drainage of the Tanana river. They thus passed near and measured, for the first time, the highest point on the North American continent—Mt. McKinley (20,464 ft.). The amount of hardship endured during the little over four months occupied by this trip, can be appreciated only by those who took part in it, and they were men who are not inclined to complain of such things. For weeks, and even months, they were pushing their heavily freighted boats against the ice-laden current of this great stream, often above their waists in the icy waters for long periods. Then, when the head of navigation was reached, they were obliged to pack on their backs all their heavy camp-stuff over a route that, because of the bulk of the material transported, had to be gone over at least twice on each day's journey. Eldridge's friends, who were familiar with his rugged vigor, were struck with the change in his appearance upon his return from this venturesome trip. The man, whom physical hardship had hitherto seemed only to render more vigorous and sturdy, at length showed evidence of physical wear. This can hardly be wondered at, for Eldridge was then in his forty-fourth year, and the experience of Survey work in Alaska has shown that exploration in the interior should be entrusted only to young men of rather exceptional vigor, if they are expected to endure more than a single season's campaign. It was at the close of this trip that Eldridge reached the crowning happiness of his life, in marrying Miss Jessie Newlands, of San Francisco, niece of the Senator from Nevada.

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[3] 17*th Annual Report U. S. Geological Survey*, Part I.

His report on the work in Alaska being completed in April, 1899, he at once resumed work on the Florida phosphates, which was again interrupted by his assignment, at the commencement of the fiscal year 1899–1900, to the study of the asphalts and bituminous-rock deposits of the entire United States. The necessary field-investigation for this work took him into no less than ten States and Territories, and occupied all his time, winter and summer, until the fall of 1900. The results of this work were published[4] in an abundantly illustrated form, and accompanied by maps of all the principal asphalt fields, practically constituting, by its exhaustive treatment, a standard monograph on this class of deposits.

In the spring of 1901, immediately upon the completion of his asphalt report, Eldridge once more resumed work on the Florida phosphates, and had brought it to within a month or two of completion, when, on the opening of the field-season, he was assigned to another investigation, which was judged to be of greater immediate importance—that of the petroleum-fields of California. He took up this work with his usual energy and thoroughness, temporarily closing his newly acquired home, near Washington, to live in California while the field-work was in progress. In the fall of 1902 he returned to Washington, to write up his report on this, his last, and, as he thought, his greatest, piece of work. From that time onward, summer as well as winter, with scarcely an interval of rest, he devoted his entire energies to the working up of the enormous amount of material he had gathered to elucidate the structure of those extremely complicated regions. His many maps and diagrams had been fully completed, the chemical and structural problems discussed, and the most important chapters of his report were not only written, but fully revised, before he was incapacitated for further work by his final illness.

The actual cause of this last sickness will, perhaps, always remain in doubt. That, with his magnificent physique, and a power of endurance that seemed inexhaustible, he should have been taken off in the prime of his manhood, was evidently due to his having overtaxed his powers, and continued confinement to the office, especially during the heats of the Washington summers, undoubtedly had a debilitating effect upon one so accustomed to an outdoor life as he was.

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[4] *22d Annual Report U. S. Geological Survey* (1900–01).

In October and November, 1904, he was laid up for a month with a peculiar illness that took the form of a low fever and baffled the physicians. In January, 1905, possibly before he was physically capable, he made a trip to Cuba to examine some asphalt-deposits, returning by way of Florida to verify the latest developments in the phosphates. This was his last field-work. Within a month after his return to the office illness again obliged him to give up work. He underwent a painful surgical operation, from the effects of which he, at first, recovered so rapidly that he expected in a few weeks to resume his nearly completed work. This relief proved, however, to be only temporary. The former physical troubles returned, caused, as it proved, by sarcoma of the kidney, and, after a painful and prolonged struggle, he finally succumbed on June 29, 1905. Through all this last illness the prevailing characteristics of his life, the combination of strength and sweetness of character, showed in strongest relief. Though doubtless conscious before all others that he was near his end, he remained cheerful and courageous to the last, and, when the fatal result could be no longer concealed from his wife, he calmly proceeded to put his worldly affairs in order in the utmost detail.

Although his two last and most important pieces of work, the studies of the phosphates of Florida and of the asphalts of California, were neither of them complete at the time of his death, they will by no means be lost, since much of his manuscript was already written and his material and notes were clearly and systematically arranged, so that they can be prepared for publication with comparatively little supplementary work.

Eldridge was remarkable for his robust physique, his strong and admirable personality, his exceptionally cheerful nature, and the keen interest with which he entered into all pursuits, whether of work or recreation. His early instructor and lifelong friend, Prof. Shaler, says of him :—

"He will remain with me as the type of the strong, well-balanced man; brave, steadfast, patient in his duties, ever friendly with his neighbors, helpful with his friends. I feel that my contacts with him served to ennoble my life."

It seems one of the inscrutable provisions of Providence that this man should have been suddenly taken away in the full vigor of manhood, and just as he was nearing the goal to which, in his public as well as in his domestic life, his great energies had been so long directed. But, admired and respected as he was by all who knew him, his energetic devotion to his work and the contagious cheeriness of his personality will ever remain an inspiring memory among his associates.

The following list comprises the papers which Mr. Eldridge has presented to the Institute:—

Title.	Volume.	Page.
The Florence Oil-Field, Colorado, . .	xx.	442–462
A Preliminary Sketch of the Phosphates of Florida, ...	xxi.	196–231

In addition to the above papers, Mr. Eldridge's publications are as follows:—

Montana Coal-Fields: *Tenth Census of the United States* (1879–1880), vol. 15, pp. 739–757 (1886).

The Industries of the Base Metals (Lead, Zinc, and Copper) in the Census Year: *Tenth Census of the United States* (1879–1880), vol. 15, pp. 809–830 (1886).

On Some Stratigraphic and Structural Relations of the Country about Denver, Colo.: *Mining Industry* (Denver, Colo.), vol. 3, No. 3, pp. 24–25; No. 4, pp. 33–35; No. 5, pp. 44–45 (1888).

Some Suggestions upon the Method of Grouping the Formations of the Middle Cretaceous, and the Employment of an Additional Term in Its Nomenclature: *American Journal of Science*, vol. 38, pp. 313–321 (October, 1889).

On Certain Peculiar Structural Features in the Foothill Region of the Rocky Mountains near Denver, Colo.: *Bulletin of the Philosophical Society of Washington*, vol. 11, pp. 247–274 (1892).

Artesian Wells of Eastern Dakota: *Compte Rendu, International Congress of Geologists*, 5th session, p. 318 (1893).

Anthracite-Crested Butte Folio, Colorado (in conjuction with S. F. Emmons and C. Whitman Cross): *Geologic Atlas of the United States, folio* 9, *U. S. Geological Survey* (1894).

A Geological Reconnaissance in Northwest Wyoming: *Bulletin No.* 119, *U. S. Geologial Survey*, pp. 72 (1894).

A Geological Reconnaissance Across Idaho: 16*th Annual Report, U. S. Geological Survey*, pt. 2, pp. 211–276 (1895).

Occurrence of Uintaite in Utah: *Science*, new series, vol. 3, pp. 830–832 (1896).

The Uintaite (Gilsonite)-Deposits of Utah: 17*th Annual Report, U. S. Geological Survey*, pt. 1, pp. 909–949 (1896).

Geology of the Denver Basin in Colorado (in conjunction with S. F. Emmons

and C. Whitman Cross): *Monograph No.* 27, *U. S. Geological Survey*, pp. 556 (1896).

Report of the Sushitna Expedition (in conjunction with Robert Muldrow); The Extreme Southeastern Coast; The Coast from Lynn Canal to Prince William Sound; The Sushitna Drainage Area; Maps and Descriptions of Routes of Exploration in Alaska in 1898, with General Information Concerning the Territory; *Special Publication of the U. S. Geological Survey*, pp. 15–27, 101–102, 103–104, 111–112 (1899).

A Reconnaissance in the Sushitna Basin and Adjacent Territory, Alaska, in 1898: *20th Annual Report, U. S. Geological Survey*, pt. 7, pp. 7–29 (1900).

The Asphalt and Bituminous Rock Deposits of the United States: *22d Annual Report, U. S. Geological Survey*, pt. 1, pp. 209–464 (1901).

Origin and Distribution of Asphalt and Bituminous Rock Deposits in the United States: *Bulletin No.* 213, *U. S. Geological Survey*, pp. 296–305 (1903).

The Petroleum-Fields of California: *Bulletin No.* 213, *U. S. Geological Survey*, pp. 306–321 (1903).

[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

The Commercial Value of Coal-Mine Sampling.

A Discussion of the Paper by Marius R. Campbell, read at the Washington Meeting, May, 1905, and published in *Bi-Monthly Bulletin*, No. 5, September, 1905, pp. 1033–1049.

Mr. A. Bement, Chicago, Ill. (communication to the Secretary*):—Mr. Campbell, in proposing his method of sampling coal-seams, has rendered an important service in insisting on the presentation of an adequate history of the sample; and it is to be hoped that his suggestion will meet with further recommendation. In my opinion it is fully as important that a complete description of the sample and the conditions surrounding its taking be given, as the results of the analysis itself; and if such should become standard practice, coal-analysis would assume greater value. As it is, the published data is very confusing, and only to an extremely small extent is it really useful.

The method suggested by Mr. Campbell, however, cannot have a general application; for example, in the Eastern Interior coal-basin, particularly at the present time, the output consists largely in grades other than mine-run, which in Illinois, for the year 1905, was only about 24 per cent. of the total product; and inasmuch as Mr. Campbell's method of sampling cannot give values for any other grade than mine-run, my contention that, at best, it can have but a limited application, is apparent. To illustrate the argument, there are two coal-seams, with the characteristics of which I am particularly familiar; each seam, as it lies in the ground, contains almost exactly 10 per cent. of ash; the lump coal from one of these seams ranges from 10 to 11 per cent. of ash, but from the other seam it does not average more than 6 per cent., although, as before mentioned, the average percentage of ash in the full seam is the same for each case.

A careful and proper sampling of coal-seams, to be followed by analysis, is to be commended in connection with all investigation; in fact, it should precede any careful study. A serious error, however, may be made in attempting to use such results to set values on the product as shipped or received. The only way that proper values can be obtained in such cases is to sample and analyze the coal as loaded or received, which, of course, will require the averaging of a large number of samples. In those cases in which the entire output is shipped as mine-run, the method proposed by Mr. Campbell certainly affords a ready means by which an approximate value may be obtained, although there is very serious danger in assuming that partings and other impurities are excluded to the extent that may be claimed.

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* Received January 22, 1906.

SUBJECT TO REVISION.

[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

The Secondary Enrichment of Copper-Iron Sulphides.*

BY THOMAS T. READ, NEW YORK, N. Y.

(Bethlehem Meeting, February, 1906.)

THE fact that certain types of ore-deposits have attained their present condition through the action of descending surface waters was, perhaps, first clearly pointed out by Posepny.[1] The oxidizing effects of such waters were discussed by Penrose,[2] and many papers dealing with this phase of the subject have subsequently appeared. That secondary enrichment of sulphide ores, however, might be produced by descending surface waters was not clearly understood until after the copper-bearing veins of the Butte district, Mont., had been carefully studied by the geologists of the U. S. Geological Survey, although De Launay[3] had suggested that sulphides might be transported from point to point and re-deposited in the zone above the level of ground-water. As a result of the study of the Butte district, two papers by geologists engaged in the work appeared within a short interval. The first by Weed,[4] dealing with the enrichment of veins by later metallic sulphides; and the second by Emmons,[5] treating of the secondary enrichment of ore-deposits in general. In the latter paper it was pointed out that a typical vein of sulphide ores which has been subjected to the action of descending surface waters exhibits four zones,—an upper or surface zone, in which the changes have been mainly of removal, the products being typically oxides; a second zone of oxide enrichment, in which the less soluble metals brought from above have been precipitated as carbonates or oxides; a third zone of sulphide enrichment, in which the materials brought down past the second zone have been deposited as sulphides; and, finally, the zone of unaltered sulphides.

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* *Contributions from the Department of Mineralogy*, Columbia University, vol. x., No. xi.

[1] *Trans.*, xxiii., 197–360 (1893).

[2] *Journal of Geology*, vol. ii., pp. 288–317 (1894).

[3] *Annales des Mines*, vol. xii., pp. 119–228 (1897).

[4] *Bulletin of the Geological Society of America*, vol xi., pp. 179–206 (1900).

[5] *Trans.*, xxx., 177–216 (1900).

In both these papers, various suggestions were made concerning the probable chemistry of the process. Somewhat later Winchell[6] detailed the results of his experiments upon the effect of solutions of $CuSO_4$ and SO_2 upon lean sulphides, and pointed out their bearing upon the production of rich sulphides, such as chalcocite, from sulphides poor in copper. Still more recently, Kemp[7] has pointed out that, in very many instances, lean sulphides are later than the rich sulphides with which they are associated, or that there may be lean sulphides which are younger and others which are older than the rich ores. In other words, the changes which have taken place are reversible, an observation which is very valuable.

In treating the chemistry of such secondary enrichment, all the foregoing writers have assumed that chalcopyrite has the formula Cu_2S, Fe_2S_3. Some years ago, Morgan and Smith[8] demonstrated that the iron of chalcopyrite is all ferrous, or, conversely, that its copper is cupric and its formula, therefore, is CuS, FeS. Obviously, this must radically affect the reactions into which chalcopyrite may enter. In the paper by Weed, already cited, little attention is paid to the valency of the copper, and copper-glance is frequently referred to as cupric sulphide. On the other hand, a writer under the pseudonym of Agricola[9] has recently criticized a reaction suggested by me for the simultaneous production of covellite and chalcocite from chalcopyrite, on the ground that the cuprous copper of the chalcopyrite could not yield cupric sulphide (covellite) in the presence of SO_2. Since the copper of chalcopyrite is cupric, this criticism is without point.

The experimental work of Winchell, already mentioned, has been so widely quoted and so extensively drawn on by others, that it seemed advisable to undertake further work along the same lines in order to elaborate more clearly, if possible, the actual processes involved in the secondary enrichment of copper-iron sulphide ores. The method followed by Winchell was to place pyrite, containing a small percentage of copper, in a sealed jar with a solution of $CuSO_4$ in one case, and of $CuSO_4$ plus SO_2 in the other. After the lapse of a considerable interval of time no effect was apparent in the jar containing $CuSO_4$ only, but in that containing SO_2 as well, the grains of pyrite had become coated with a blue-black coating resembling chalcocite. From these results and some other chemical experiments it was inferred that $CuSO_4$ was without action on lean sulphides, and that the SO_2 reduced the $CuSO_4$ to Cu_2SO_4, which then reacted on the pyrite to form $FeSO_4$, Cu_2S and S.

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[6] *Bulletin of the Geological Society of America*, vol. xiv., p. 269 (1903).

[7] *Economic Geology*, pp. 11-26 (1905).

[8] *Journal of the American Chemical Society*, vol xxiii., p. 107 (1901).

[9] *Engineering and Mining Journal*, vol. lxxix., p. 1147 (1905).

In conducting further experimental work, an attempt was made to imitate natural conditions as nearly as possible. Coarsely-crushed pyrite and chalcopyrite were placed in open glass tubes, and a solution of $CuSO_4$ was allowed to percolate slowly through one and a solution of $CuSO_4$ plus SO_2 through the other; 100 cc. of a 1.5-per cent. solution was used in each case, being passed through from 15 to 20 times in the course of two weeks. At the end of that time the solutions were analyzed, which showed that, in the case of the $CuSO_4$ plus SO_2, the percentage of copper present had decreased, and a notable amount of the iron had gone into solution as $FeSO_4$. In the case of the $CuSO_4$ alone, a small amount of iron had gone into solution. In using this method, it proved so difficult to prevent various losses, as well as to guard the ore and solutions from the effects of vagrant gases in the laboratory, that it was abandoned, and a study of the reactional changes in closed vessels was substituted in its place. Small (150-cc.) bottles were used for this purpose. For the original copper-iron sulphide, chalcopyrite, crushed between 40 and 100 mesh, was selected, and in order that the enrichment changes might have opportunity partly to establish themselves, it was warmed with dilute $CuSO_4$ solution until it became distinctly tarnished, and then washed and dried. An analysis showed it to contain Cu, 32.62, and Fe, 27.24 per cent. Ten grams of this material were placed in each bottle, and 100 cc. of each of the following solutions were added to the corresponding bottle:—

1. A solution of copper sulphate containing 3.6 mg. of copper per cc., saturated with SO_2 gas.

2. A solution of copper sulphate containing 3.6 mg. of copper per cc.

3. Distilled water saturated with SO_2 gas.

4. A solution of calcium bicarbonate.

The bottles were closely stoppered with rubber stoppers, which enclosed about 40 cc. of air above the level of the solution. They were shaken daily, and allowed to stand for a month.

At the end of the month the solutions were filtered off, the residue washed, dried and weighed, and both were analyzed. The results obtained were as follows:—

1. *Copper Sulphate and Sulphur Dioxide Gas.*—The loss in weight of the copper-iron sulphide was 4.6 per cent. The composition of the enriched sulphide was:—Fe, 26.86 per cent., a loss of 0.38 per cent.; and Cu, 33.90 per cent., a gain of 1.28 per cent. The composition of the solution was:—Fe, 3.43 mg. per cc., a gain of 3.43; Cu, 3.38 mg. per cc., a loss of 0.22; and SO_3, 9.91, a gain of 5.38 mg. per cc.

The enriched sulphide was dark green in color; during the month it had been successively bronzy, purple and dark steely blue. A few brassy grains could be seen.

2. *Copper Sulphate Alone.*—The composition of enriched sulphide was:—Fe, 27.30 per cent., a gain of 0.06 per cent.; and Cu, 33.77 per cent., a gain of 1.15 per cent. The composition of the solution was:—Fe, 0.1 mg. per cc., a gain of 0.1; Cu, 3.25 mg. per cc., a loss of 0.35; and SO_3, 5.1 mg. per cc., a gain of 0.57.

The color of the sulphide had not appreciably changed.

3. *Water and Sulphur Dioxide.*—The loss in weight of the copper-iron sulphide was 5.04 per cent. The composition of enriched sulphide was:—Fe, 26.95 per cent., a loss of 0.29 per cent.; and Cu, 34.06 per cent., a gain of 1.44 per cent. The composition of the solution was:—Fe, 2.67 mg. per cc., a gain of 2.67; Cu, 0.06 mg. per cc., a gain of 0.06; SO_3, 3.81 mg. per cc., a gain of 3.81.

The sulphide was a lustrous blue, almost exactly like covellite, although scattered purple and brassy grains could be detected.

4. *Calcium Bicarbonate.*—The calcium bicarbonate solution was prepared by treating the dust of a very pure marble with

ordinary carbonated or "vichy" water, filtering, and adding carbonated water until the cloudiness disappeared. The strength of the solution so prepared was 0.15 mg. of CaO per cc. The copper-iron sulphide showed a loss in weight of 0.1 per cent. It had not changed appreciably in appearance. The solution contained 0.36 mg. of SO_3 per cc. and very small amounts of iron and copper; but, unfortunately, it was not possible to make their determination until after some CO_2 had escaped, causing a precipitation of $CaCO_3$ and a consequent alteration of the composition of the solution.

The solid residue effervesced slightly with hydrochloric acid, showing a partial change to carbonates. It was plain that, to some extent, the calcium bicarbonate had formed calcium sulphate and carbonates of iron and copper.

In considering the foregoing results, the most important point of interest is that the solution containing SO_2 alone had attacked the copper-iron sulphide, with the resultant formation of $FeSO_4$, the amount of $CuSO_4$ formed being very small, indeed. There is no free sulphuric acid present. Whether the sulphide acts as a catalyzer, oxidizing the sulphurous to sulphuric acid, which immediately reacts with the sulphide, or whether the sulphurous acid attacks the sulphide forming sulphites, which are then oxidized to sulphates by the dissolved air, is not evident. The important fact is clear, however, that waters, containing SO_2 and O, will attack copper-iron sulphides, abstracting the iron and removing it in the form of $FeSO_4$, the enrichment of the sulphide being due to the removal of its iron.

In the case in which $CuSO_4$ and SO_2 were used, a similar action had taken place, but the removal of the iron and production of $FeSO_4$ had been greater. The solution also showed a loss in copper, so that, evidently, the $CuSO_4$ had reacted with the copper-iron sulphide, exchanging its copper for the iron of the sulphide.

In the case of the $CuSO_4$ alone, copper was removed from the solution and the copper-iron sulphide was enriched in copper. But there was very little $FeSO_4$ produced, the action apparently being a reduction of the $CuSO_4$ by the sulphide and the production of free sulphuric acid. Why the free sulphuric acid does not attack the sulphide is puzzling, and how, under the circumstances, there could be a gain in the SO_3 is no less so. The difficulty of obtaining a uniform mixture of this coarsely crushed material was great.

In the case of the calcium bicarbonate solution the action was very slight.

An important factor in the enrichment of copper-iron sulphides is the removal of the iron, either in solution as sulphate or by simple oxidation. This is also seen by a study of the veins themselves. Weed[10] mentions that, at Gold Hill, N. C., the oxidized ore is bordered by massive copper-glance, and, in numerous other localities, this phenomenon is less clearly shown. Very similar is the action of kernel-roasting of low-grade copper-iron sulphides, when, by oxidation of the iron, an enriched core is produced, resulting, finally, in the production of a button of metal, *i.e.*, copper, at the center, if the action is pushed to its limit. The oxidizing action being slow, the copper retreats toward the center as the iron is oxidized. Just how this is accomplished is not known, but it seems to be a slow molecular flow, which, like the formation of concretions, is not yet clearly understood.

The most important feature of the foregoing is the demonstration that it is unnecessary to provide an hypothesis to explain the reduction of copper from bivalency to monovalency, during the process of enrichment. The auto-reduction of the copper by the successive removal of the iron and sulphur by oxidation is quite similar to that which takes place in the converting of a low-grade matte. Indeed, Cu_2S, compared with Cu_2S_2, is a partly oxidized salt, for the latter will require twice as much oxygen as the former, in order to form metallic copper. It is clear, then, that oxidation alone is sufficient to produce the enriched sulphides occurring in the zone of secondary enrichment. That the removal of the iron and sulphur has usually sufficed for this enrichment, is not to be believed, since the diminution of volume must then produce very porous ore-bodies. That the retreat of the copper before the advance of the oxidizing zone can carry it to any great distance has yet to be demonstrated. Probably removal by simple oxidation and reaction with descending sulphates have both operated, perhaps simultaneously. It cannot be doubted that the processes and actions involved in the production of such ore-bodies have not only varied somewhat in different regions, but also in each individual case, since the conditions change from time to time. The degree of concentration of the solution, the potent influence of very small quantities of dissolved salts in affecting the action of other salts in the same solution, the effect of mass;—all these complicate the problem.

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[10] *Bulletin of the Geological Society of America*, vol. ii., p. 191.

Excluding the ore-deposits of igneous origin, in the present state of our knowledge it seems clear that ore-bodies have been formed by the slow action of dilute solutions. In some cases, these dilute solutions have been the waters escaping from the solidification of igneous intrusives. In others, vadose waters have removed the scattered metallic contents of the rocks, only to concentrate them in a vein. Finally, descending waters may remove the metallic contents of the upper part of an ore-deposit, concentrating them at lower levels. The infinitude of possible varieties of products and reactions has contributed to make the study of ore-deposits a puzzling one indeed, and the greatest credit is due to the economic geologists and mining engineers who, by their keen observation and sagacious inference, have contributed so much to the elucidation of this subject.

SUBJECT TO REVISION.

[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

The Relative Merits of Large and Small Drilling-Machines in Development Work.

BY FREDERICK T. WILLIAMS, E.M., VICTOR, COLO.

(Bethlehem Meeting, February, 1906.)

THE purpose of this paper is to discuss the relative merits of the large 3⅛-in. machine and the small 2¼-in. tappett machine in driving development-headings; and although the data here presented were obtained from cross-cut headings alone, experience has shown that the results are equally true in drifting, raising and winzing.

Recently we drove two parallel cross-cuts through the same formation, using a 3⅛-in. machine at the breast of one cross-cut, and a 2¼-in. machine of the same make at the breast of the other. The results of this work afforded an ideal comparison, since in both cases the headings were advanced through rock practically of the same hardness and breaking-properties; the amount of sludging was equal, and there was no difference in the condition of the steel or the machines, in the air-pressure or in the experience of the operating-crews.

Some operators in the Cripple Creek district contend that there is ground which cannot be handled with the small machine, the holes being too small to contain enough powder to pull the ground, etc. The results obtained in working the property of the Portland Gold Mining Co., however, show that the ground worked by them does not fall in this class. During a period of two years there have been driven, with the small machine, 4 miles and 308 ft. of development-headings, through a diversity of ground, including Pike's Peak granite (a coarsely porphyritic type of granite), highly indurated, andesitic or phonolytic breccia, true massive andesite, trachytic phonolyte, tuffas, and along dikes of decomposed basalt and hard phonolyte; in every instance a satisfactory record was made.

The headings here described were driven through highly indurated, andesitic breccia, having a hardness of from 5.2 to 7.2

and a sp. gr. of from 2.2 to 2.8. The action of the breccia under the drill was not materially different from that of ordinary red granite. The breccia was not as free-drilling as granite, and sludge accumulated very rapidly after a shallow depth of hole has been gained, but it broke better than granite.

Aside from the usual work of setting-up, drilling, and loading, the machine-men or helpers mucked back, cleaning the floor 3 or 4 ft. back from the breast of muck in order to position the column properly. If the "lifters" acted properly at the previous firing, the muck was fairly-well thrown back from the breast; but if either missed fire or were exploded before the other holes, considerable muck was left at the breast which required much additional labor. The usual time needed to muck back was 1.25 hr., but this varied considerably. Flat steel, 48 by 96 by ⅜-in. sheets, were used, from which to shovel the material. These sheets were placed in position 3 or 4 ft. back from the breast by the trammer just before going off shift. The ground broke fine enough to require little or no sledging. A cubic foot of breccia in place will average 154 lb. in weight as compared with 90 lb. on the muck-pile, giving an average of 42 per cent. of void space. All the waste was trammed to the shaft, 800 ft. distant, and hoisted to the surface. No timber was used in either heading.

The following interesting summary of the results obtained by using both large and small machines has been prepared from the data given in Tables I. and II. Labor is the largest individual item. The wages of machine-men was $4 per shift, and the addition of the items given under the several heads of Table I. shows the total cost of labor performed in each heading. The cost of operating the machines per shift was $3.70 for the large machine and $1.85 for the small machine; these figures, which vary from month to month, include the cost of everything connected with the operation of the machines: engineer's wages, blacksmith expense, new steel repairs to the machines, cost and repair of air-lines, etc. The cost of labor, per foot driven, by the large machine was $3.45, and by the small machine $2.56.

The cost of explosives, a detailed report of which is given in Table II., shows that the 40-per cent. dynamite costs $0.127 per lb.; the fuse, $0.0035 per ft.; and the caps, $0.007 each.

TABLE I.—*Development Report of the Portland Gold Mining Co. for 20 days Ending Oct. 16th, 1903.*

[3]

	Machine Men.	Machine Helpers.	Hand Miners.	Trammers.	Pipe and Trackmen.	Total Labor.	Cost of Labor per Foot.	Number of Machine Shifts Worked.	Cost of Operating Machines.	General Tramming Cost.	Explosives, Including Powder, Fuse, and Caps.	Cost of Explosives per Foot.	Cost of Pipe and Track.	Cost of Hoisting.	Cost of Supplies.	General Expense, Bosses, Assaying, Surveying, Etc.	Total Cost.	Cost per Foot.	Total Tons.	Cost per Ton.	Number of Feet Driven.	Feet per Shift.
Large machine (3¼″). Cross-cut (5.5′ x 7.5′).																						
5 day run..............................	$40	$35	....	$22.13	$3.00	$100.13	$3.51	10	$37.00	$0.99	$66.22	$2.32	$11.69	$22.69	$0.79	$22.69	$262.20	$9.20	99.20	$2.64	28.5	2 85
8 day run..............................	64	56	....	31.13	3.75	154.88	3.33	16	59.20	1.42	90.20	1.93	19.07	32.57	1.14	32.57	391.05	8.41	142.40	2.75	46.5	2.91
7 day run..............................	56	42	....	28.13	....	126.13	3.55	14	51.80	1.10	72.84	2.05	14.56	25.26	0.88	25.25	317.81	8.95	110.40	2.88	35.5	2.54
Averages and totals.........	160	133	....	81.39	6.75	381.14	3.45	40	148.00	3.51	229.26	2.07	45.32	80.51	2.81	80.51	971.06	8.79	352.00	2.76	110.5	2.76
Small machine (2¼″). Cross-cut (4.5′ x 7.0′).																						
5 day run..............................	40	......	$0.75	17.25	1.88	59.88	2.49	10	18.50	0.63	36.55	1.52	9.84	14.46	0.52	14.46	154.83	6.45	63.20	2.45	24.0	2.40
8 day run..............................	64	......	....	31.88	3.75	99.63	2.49	16	29.60	1.09	53.01	1.32	16.40	24.89	0.87	24.89	250.38	6.26	108.80	2.30	40.0	2.50
7 day run..............................	56	......	....	30.38	3.75	90.13	2.69	14	25.90	1.10	36.71	1.09	13.74	25.08	0.88	25.08	218.62	6.53	109.60	1.99	33.5	2.39
Averages and totals.........	160	......	0.75	79.51	9.38	249.64	2.56	40	74.00	2.82	126.27	1.29	39.98	64.43	2.27	64.43	623.83	6.40	281.60	2.22	97.5	2.44

These figures, which include freight, unloading, wages of the powder-man, and one-third of the wages of the store-keeper, represent the entire cost of the material, as laid down at the station for the machine-men. All fuse burned was in 7-ft. lengths. The number of feet of fuse burned and the number of caps used, per foot, are practically the same, but the cost of dynamite is $0.78 less, per foot, in the heading driven by the small machine than in that of the large machine.

TABLE II.—*Explosives—Detailed Report of the Portland Gold Mining Co. for 20 days Ending Oct.* 16, 1903.

	Lb. of Powder.	Lb. of Powder per Foot Driven.	Feet of Fuse.	Feet of Fuse per Foot Driven.	Number of Caps.	Number of Caps per Foot Driven.
Large machine (3⅛″). Cross-cut (5.5′ x 7.5′).						
5 day run	491	17.23	872	30.59	116	4.07
8 day run..................	669	14.39	1,179	25.35	158	3.39
7 day run..................	544	15.32	804	22.65	134	3.77
Averages and totals.	1,704	15.40	2,855	25.80	408	3.69
Small machine (2¼″). Cross-cut (3.5′ x 7′).						
5 day run	264	11.00	672	28.00	96	4.00
8 day run..................	378	9.45	1,129	28.22	151	3.77
7 day run..................	262	7.82	742	22.15	120	3.58
Averages and totals.	904	9.27	2,543	26.08	367	3.76

The best record for a shift's run, made by the large machine, was 4.08 ft., as compared with 2.96 ft. for the small machine. In drilling these rounds it was found that the large machine had made 3109.56 cu. in. of hole, and the small machine 971.10 cu. in. Comparing these figures with the cubic feet of ground pulled, 1 cu. in. of hole drilled by the large machine broke 0.053 cu. ft. of breast, while the small machine gave 0.097 cu. ft. This comparison shows that too much work was done by the big machine on the breast for the amount of ground broken.

Figs. 1 and 2 show the number of holes drilled, the degrees of pitch from the horizontal, the depth drilled by the starters, seconds and thirds, and the order of firing. The cost of coal before the boilers was $4.40 per ton. Ordinary cross or square

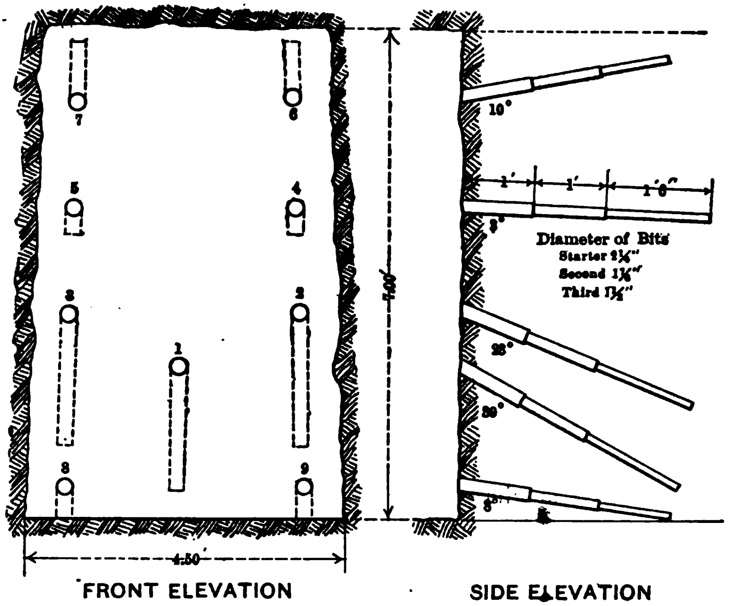

FIG. 1.—HOLES DRILLED IN BREAST BY SMALL (2¾-IN.) MACHINE.

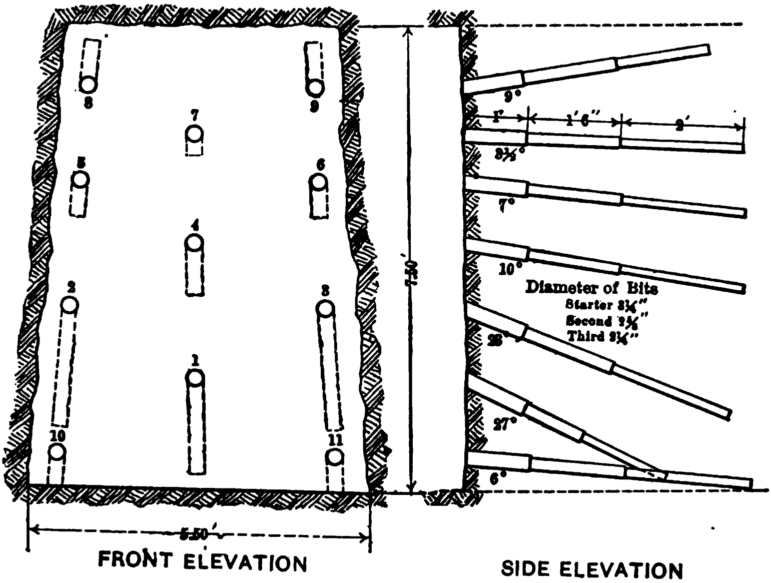

FIG. 2.—HOLES DRILLED IN BREAST BY LARGE (3⅛-IN.) MACHINE.

bits were used, and all the steel was sharpened by machine. At each sharpening the steel lost from ⅛ to ⅜ in. in length. The general tramming-cost includes repairs to tram-cars, tram-tracks and the greasing of the cars.

The cost of pipe and track is figured at $0.41 per ft., the 2-in. pipe costing, with connections, $0.10 per ft., the track, together with the spikes, plates and ties, costing $0.31 per ft. Lumber costs $20 per thousand feet.

Hoisting cost $0.243 per ton, which includes all accounts that can be charged to the maintenance of the hoisting-engines;—such as wages of the engineers, wipers, top-men and cagers, repairs, cost of steam, cables and repairs to shaft. The hoist used is a 500-h.p. Webster, Camp & Lane, first-motion hoist, size 20 by 48 in., having a capacity for a maximum depth of 2,500 ft., using 5 by ⅜ in. rope to hoist an unbalanced load of 8,000 lb. at an average speed of 1,500 ft. per min.

To supplies is charged the cost of picks and shovels. To general expense is charged the wages of foremen and shift bosses, assaying and surveying, pumping, lighting, including candles, office expense and general repairs on the surface.

The air was furnished by a 50-drill, cross-compound, Ingersoll-Sargent compressor, having steam-cylinders 24 by 44 by 48 in., and air-cylinders 22¼ by 38¼ by 48 in. The air-pressure at the receiver was 100 lb., and at the drills 85 lb. per sq. in.

The bore of the large machine cross-cut is 5.5 by 7.5 ft., that of the small machine is 4.5 by 7 ft.; it is held that the increase of 1 ft. in width and 0.5 ft. in height of the large machine cross-cut over that of the small machine cross-cut does not facilitate mining-operations in any way.

The merits of the work done by the two machines may be briefly stated thus:—The use of the small machine saves 25 per cent. of the cost of labor necessary to operate a large machine foot per foot. The cost of operating a small machine is 50 per cent. less than that of operating a large machine, shift for shift. The general tramming-cost of the large machine cross-cut is lessened 20 per cent. by using a small machine. The cost of explosives per foot driven by the large machine can be reduced 37.7 per cent. by the use of the small machine. The cost of hoisting and general expense of the large machine cross-cut is lessened nearly 20 per cent. by using the small machine.

Greater speed, regardless of cost, can be obtained with the large machine, the small machine being from 10 to 20 per cent. slower. The cost of the large machine cross-cut was reduced 27 per cent. by using the small machine.

In conclusion, I wish to acknowledge my indebtedness to Mr. Frank L. Smale, Superintendent of the Portland property, for assistance received in gathering the data here presented.

[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

Comparison of Methods for the Determination of Iron and Phosphorus in Steel.

Continued Discussion of the Paper of Messrs. von Jonstorff, Blair, Dillner and Stead, presented at the New York Meeting of the Iron and Steel Institute, October, 1904.*

(Bethlehem Meeting, February, 1906.)

Clemens C. Jones, Richmond, Va. (communication to the Secretary†):—In the chapter of this paper entitled "Method for the Determination of Phosphorus," by Andrew A. Blair, a form of the reductor used by Mr. Blair is illustrated. This form was employed by me in my earliest experiments, and abandoned after my adoption of the final apparatus described in my paper[1] on the subject in 1889. The results reported by Mr. Blair are very closely accordant; but my experience was that, in the use of this form, a loss of the solution, amounting to almost a cubic centimeter, was occasioned by minute bubbles of hydrogen rising to the surface, and there exploding. My final reductor was designed to prevent this loss; and the most satisfactory results were obtained with a reductor having the open cup replaced by a bulb-shaped receptacle, provided with a glass stopper, similar to that of a separatory funnel of similar capacity, as suggested in a foot-note in my original paper. In my experience, the use of this later form of reductor repeatedly gave duplicate results which were coincident to the fourth decimal place.

R. W. Raymond, New York, N. Y.:—The remarks of Mr. Jones recall to my mind an interesting part of the history of the Institute, and of its relation to modern progress in the department covered by this interesting and valuable paper. In my Biographical Notice of the late Thomas M. Drown,[2] I have emphasized his leadership, and his powerful influence, through personal investigations and publications, and through the inspiring example and guidance given to his pupils, in promoting the employment of chemists by manufacturers, and (as a means to that end) in perfecting the methods and apparatus for simple, rapid and accurate commercial analyses. The volumes of our *Transactions*, in their "Symposiums" and other comparisons and discussions of analytical laboratory-methods, bear witness to the profoundly important and extensive results of the movement in which he took so influential a part; and in no other field is this more impressively shown than in that of the chemical analysis of iron-ore, iron and steel.

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* Published, by mutual agreement between the Councils of the two Institutes, in the *Bi-Monthly Bulletin* of this Institute for March, 1905, but not in the annual volume of the *Transactions*. See, also, in the *Bi-Monthly Bulletin* for May, 1905, a discussion by R. Hamilton and others.

† Received February 6, 1906.

[1] *Trans.*, xvii., 413.

In 1878, Dr. Drown published a paper[3] on the uses of pulverized zinc as a precipitant in the laboratory. Like many other stimulating suggestions made by him, this was taken up in practice by his pupils and others, who were at that time beginning to be employed at manufacturing establishments previously accustomed to "get along" without chemical laboratories of their own. One of the earliest companies to adopt this policy was the Thomas Iron Co., which set up a laboratory at Hokendauqua, Pa., and employed as chemist Mr. Clemens C. Jones. Mr. Jones soon made himself known by novel and ingenious investigations and experiments, of which, for my present purpose, I need mention only two, which are recorded in our *Transactions*.

At the New York meeting of the Institute, in February, 1889, Mr. Jones presented his paper on "A Rapid Method for the Reduction of Ferric Sulphate in Volumetric Analysis," in which a new method of employing pulverized zinc as a precipitant was described and illustrated. It goes without saying that Drown's suggestion, made eleven years earlier, had not passed through that period without attention. Indeed, at a meeting of the Chemical Society at London, April 5, 1888, a paper was read by Mr. D. J. Carnegie on "The Action of Finely-Divided Metals on Solutions of Ferric Salts, and a

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[2] *Bi-Monthly Bulletin* for July, 1905, p. 859, and p. 288 of Vol. XXXVI. of the *Transactions*, now in press.

[3] *Trans.*, vi., 508.

Rapid Method for the Titration of the Latter."[4] In the discussion of this paper, the author acknowledged that the use of powdered zinc had been suggested "some years ago" by Drown. (The *Chemical News* printed it *Brown*—such is earthly fame!)

But neither Dr. Drown nor Mr. Carnegie nor anybody else, so far as I can find out, proposed the one thing required to remove the practical objections to this use of zinc. The latest practice, as set forth by Carnegie, was to put zinc-dust into the solution under treatment, and "shake" it. In the following year, Mr. Jones not only proved experimentally, but designed an apparatus for utilizing in practice, the fact that "a solution of ferric sulphate is instantaneously and completely reduced by filtering through pulverized zinc,"[5] and thus made the method practicable, by removing certain difficulties attending its use, which I need not here pause to discuss, since they are sufficiently set forth in the publications already cited.

The apparatus designed by Mr. Jones for this operation he called a "reductor." I have always understood that the name, as well as the thing, originated with him; and I remember that Dr. Drown agreed with me in regarding it as a most important contribution to practice in the rapid and accurate analysis of iron-ore, iron and steel. In his contribution to the present discussion, Mr. Jones has given reasons for his opinion that the form of reductor used by Mr. Blair is inferior to the form which he himself finally preferred, after trying both. But he has modestly refrained from asserting his claim as the originator of this apparatus, and of its use in the laboratory. In a subsequent paper,[6] Mr. Jones pointed out that the method and apparatus introduced by him for reducing ferric solution, with the aid of his reductor, applied "in all respects equally well to the complete and instantaneous reduction of molybdic acid."

The later paper of Mr. Jones, last cited, was presented at the Washington meeting of February, 1890, under the title, "Phosphorus in Pig-Iron, Steel and Iron-Ore." Under that head the previously-suggested methods of analysis were discussed, and a procedure based upon extensive laboratory-experiments was recommended. If I am not mistaken, this method is essentially the one described in the paper before me, as adopted by Mr. Blair.

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[4] *Chemical News*, vol. lvii., No. 1481, April 13, 1888, p. 148.

[5] *Trans.*, xvii., 413 (1889).

[6] *Trans.*, xviii., 709.

Mr. Jones offered other suggestions in the line of laboratory-methods, which, taken together with those I have mentioned, entitle him, in my opinion, to recognition among those acute investigators and practitioners who have brought about a distinct revolution and reconstruction of modern practice. It is to be regretted, from my present standpoint, that he did not continue in the special work which he so brilliantly began, but was diverted into other professional and business fields.

In thus recalling his early contributions, I wish to say that I do not by any means blame the authors of this paper for omitting to mention his name. It would be absurdly unreasonable to require, in an up-to-date treatise, the specific recognition of all previous contributions to the progress which it summarizes. Possibly it might be urged that the "Jones reductor" has as good a claim to individuality as the Erlenmeyer flask, the Griffin beaker, the Liebig bulb, or the Bunsen burner. But I have no desire to criticise, in such a treatise as this, the mere omission of a name. I do not find fault with the *omission;* I wish only, in justice to the Institute and one of its members, to complete the record by supplying the *name.*

As Secretary of the Institute, and Editor of its *Transactions* for 22 years past, I may be pardoned for some jealousy concerning its fame, as the channel through which important discoveries and improvements, in the numerous branches of science and practice represented by its membership, have been first made known. This feeling is my excuse for the foregoing remarks.

SUBJECT TO REVISION.

[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

The Constitution of Mattes Produced in Copper-Smelting.

A Discussion of the Paper by Allan Gibb and R. C. Philp, read at the Lake Superior Meeting, September, 1904, and published in *Bi-Monthly Bulletin*, No. 6, November, 1905, pp. 1193 to 1210.

Edward Keller, Baltimore, Md. (communication to the Secretary*):—The authors of this paper are to be commended for their industry and congratulated upon the many interesting results which were the fruit of their researches. While thoroughness has marked their work in general, yet on a few points in particular they have touched but lightly, for which reason, it would appear to me, they have hit wide of the mark in their respective conclusions.

The work alluded to pertains chiefly to the occurrence of magnetic iron oxide (ferroso-ferric oxide) in copper-mattes. Because the authors find that the magnetic residue, left by the dissolved sulphides, varies largely in quantity according to the strength of nitric acid used (with potassium chlorate) in dissolving the mattes, they conclude :—

> "It appears that the ferroso-ferric oxide is the result of precipitation by the oxidizing agent, rather than an original constituent of the matte."

In this part of their investigation, Messrs. Gibb and Philp have ignored some well-established data. In the first place, they have overlooked the fact that there are mattes which are strongly magnetic and others which scarcely show any magnetic property. There is nothing in their work tending to explain this variation. They seem to have tested none of their products for magnetism. Secondly, they have overlooked the fact that magnetic iron oxide probably exists in all ore-charges in the copper-matting furnaces, and, under the given conditions, that this oxide is very difficult to reduce and to combine with silica to form slag. Thirdly, they pay no attention to the varying specific gravity of the several grades of copper-matte, which may exceed, equal, or fall below that of the magnetic oxide. These are essential points which, I believe, clearly indicate the great probability that magnetic oxide must enter into such mattes as have an equal or a lower specific gravity than its own. I have corroborated this conclusion by analytical results, having found low-grade mattes, from reverberatory furnaces, to be strongly magnetic and to contain a considerable percentage of magnetic oxide, while high-grade mattes of the same origin were non-magnetic and showed very little magnetic oxide;—the latter, in such cases, remaining with the slags. Low-grade mattes which are non-magnetic yield no magnetic oxide, for which no reason is given by the authors' theories.

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* Received February 7, 1906.

The conclusion of Messrs. Gibb and Philp, that ferroso-ferric oxide is formed from iron proto-sulphide by the oxidation with strongest nitric acid and potassium chlorate, is not only very much against "*das chemische Gefühl,*" but also contrary to all chemical precedent. These reagents convert many metals into their peroxides, and it seems incredible that the readily oxidizable iron protoxide could pass through their solution unoxidized, and be precipitated as a crystalline ferrous compound, at what might be called ordinary temperature.

While I agree with the authors that magnetic oxide probably plays no part in the chemical constitution of the mattes (*i.e.*, the sulphides), yet I know of no data to prove that the oxide was not dissolved in the sulphides in their molten state and segregated upon their solidification. Be that as it may, the authors' statement that the magnetic oxide derived as a residue from mattes shows different solubility in acids from that of other forms of magnetic oxide produced at high temperature, may be more rationally explained by the assumption that they differ in character of molecular aggregation, than by the assumption that one of them is precipitated by liquid oxidizing agents.

What the authors have established regarding the condition of excessive iron in mattes is most interesting. They show that it is not present in chemical combination with its proto-sulphide, or in any visible form as metallic iron, but that the iron proto-sulphide is capable of retaining the metal in solid solution to the extent of 24 per cent. It would be valuable to know if this solution of sulphide and metal is magnetic. I have found mattes with excessive iron to be non-magnetic. The discovery of the state of solid solution may, in a way, explain the absence of the magnetic property of the metal. The condition of solid solution implies that the iron is not in the ordinary crystalline form, but rather in an allotropic, amorphous modification.

SUBJECT TO REVISION.

[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

Bibliography of Coal-Washing.

BY SAMUEL S. WYER, COLUMBUS, OHIO.

(Bethlehem Meeting, February, 1906.)

The following abbreviations have been used in the text:—

Am. Mf. and Iron World. *American Manufacturer and Iron World*, Pittsburg, Pa.

Can. Min. Rev. *Canadian Mining Review*, Ottawa, Can.

Cass. Mag. *Cassier's Magazine*, New York, N. Y.

Col. Eng. *Colliery Engineer*, London, Eng.

Col. Guard. *Colliery Guardian*, London, Eng.

Eng. and Min. Jour. *Engineering and Mining Journal*, New York, N. Y.

Eng. News. *Engineering News*, New York, N. Y.

Engr. *Engineering*, London, Eng.

J. I. and S. I. *Journal of the Iron and Steel Institute*, London, Eng.

Jour. W. Soc. of Engrs. *Journal Western Society of Engineers*, Chicago, Ill.

Lond. Eng. *The Engineer*, London, Eng.

Mines and Min. *Mines and Minerals*, Scranton, Pa.

North of Eng. I. M. E. *North of England Institute of Mining Engineers*, Newcastle-on-Tyne, England.

Oester. Zeitsch f. Berg u. Hüt. *Oesterreichische Zeitschrift für Berg. und Hüttenwesen*, Vienna, Austria.

Pract. Engr. *Practical Engineer*, London, Eng.

Proc. I. C. E. *Proceedings Institution of Civil Engineers*, London, Eng.

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Kohn, *Iron and Steel Manufacture*, p. 2 and 3, 28, 29 and 30. References to washed coal.

1869.

Van Nostrand's Magazine, vol. 1., p. 280. Brief mention of coal-washing industry in France.

1870.

Crookes and Röhrig, *Treatise on Metallurgy*, p. 457. Desscription and illustrations of several early types of coal-washers.

Van Nostrand's Magazine, vol 2, p. 337. Elaborate description of coal-washing machinery. Discusses impurities in coal, advantages of washing, sizing, principle of coal-washing, various types of machines and the drying of the coal.

1872.

F. C. Danvers, *Coal Economy*, p. 92. Monograph on coal-washing.

1873.

Trans. A. I. M. E., vol. 1, p. 223. Brief mention of value of washed coal.

1874.

Proc. I. C. E., vol. 40, p. 323. Abstract of article describing a machine for simultaneously washing and sorting coal.

Spon's Dictionary of Engineering, vol. 1, p. 979. Illustration and description of coal-washing plant.

1875.

Trans. A. I. M. E., vol. 3, p. 172. Description and illustration of coal-washing plant, with summary of results.

1876.

Eng. News., July 15, vol. 3, p. 228. Coal-washing in Illinois. Gives description, illustration and considerable valuable data.

Mineral Resources West of the Rocky Mountains, p. 434. Discussion of the action of small spheres of solids in ascending currents of fluids.

1877.

Knight's Mechanical Dictionary, vol. 1, p. 579 and 581. Illustration of coal-washing machines.

Bulletin de la Société de l'Industrie minerale. Description and discussion of French coal-washers.

Proc. I. C. E., vol. 55, p. 259. Extensive discussion of the theory of coal-washing, importance of sizing and description of several French coal-washers. Gives considerable valuable data.

1879.

J. I. and S. I., p. 295. Brief mention of the field for coal-washers.

North of Eng. I. M. E., vol. 29, p. 159. Illustration and description of the Lührig coal-washing system. Gives valuable data on results of washing.

1880.

Davies, *Metalliferous Minerals and Mining*, p. 357. Discussion of jigging.

J. I. and S. I., vol. 1, p. 210. Brief discussion of Sheppard's coal-washer.

J. I. and S. I., vol. 2, p. 629. Discussion of the use of washed coal for coking purposes.

Revue Industrielle, p. 105. Description and discussion of the operation of a new type of machine for washing and sorting coal.

1881.

Iron Age, February 3. Description and discussion of the operation of the Stutz coal-washer. Gives summary of results obtained.

Iron Age, March 31. Abstract of paper on coal-washing machinery.

J. I. and S. I., vol 1, p. 266. Brief description of a coal-washer.

J. I. and S. I., vol 2, p. 680. Brief discussion of the progress of coal-washing in Belgium.

Proc. I. C. E., vol. 64, p. 426. Abstract of article on the Stutz coal-washer.

Trans. A. I. M. E., vol. 9, p. 461 and 474. Elaborate description and illustrations of sizing and washing machinery, with discussion of principles involved and application of Rittenger's investigations.

1882.

Engr., vol. 33, p. 518, May 19. Abstract of paper on coal-washing. Gives summary of results with different machines.

Proc. I. C. E., vol. 70, p. 106. Extensive description and elaborate drawings of an English coal-washing plant. Gives much valuable data.

School of Mines Quarterly (New York), vol. 3, p. 218. Discussion of the value of assays for the control of coal-washing.

1883.

J. I. and S. I., vol. 1, p. 274. Description and discussion of the operation of a German coal-washing plant.

1884.

J. I. and S. I., vol 2, p. 573. Description of the "Circulator" coal-washer.

J. I. and S. I., vol. 2, p. 700. Brief reference to the calcium chloride method of separating coal.

North of Eng. I. M. E., p. 58, abstracts. Lengthy abstract of a French article on coal-washers, which gives considerable data.

Trans. A. I. M. E., vol. 12, p. 497. Description and illustration of the Stutz coal-washer.

1885.

J. I. and S. I., vol. 1, p. 269. Brief description of a new coal-washing plant.

Mechanics, November. Brief discussion of washed coal.

Trans. A. I. M. E., vol. 13, p. 341. Experiments on the separation of coal by means of a calcium chloride solution.

1886.

Bulletin No. 36, U. S. Geological Survey. Comprehensive investigation of the subsidence of fine solid particles in liquids. This paper is of unusual value, and it gives a large amount of data.

1887.

Eng. and Min. Jour., vol. 44, p. 3. Short article on coal-washing. Gives considerable condensed information.

J. I. and S. I., vol. 2, p. 276. Brief description of a German coal-washing plant.

North of Eng. I. M. E., vol. 37, p. 70, abstracts. Abstract of a French article describing a new form of coal-washer.

Stahl und Eisen, vol. 7, p. 553. Description of a German coal-washing plant.

1888.

J. I. and S. I., vol. 1, p. 282. Brief discussion of the coal-washing industry in the United States.

J. I. and S. I., vol. 2., p. 225. Description of two coal-washing plants.

1890.

Eng. and Min. Jour., vol. 50, p. 48, July 12. Brief description and discussion of a new form of coal-washer.

J. I. and S. I., vol. 1, p. 271. Description and discussion of the cleaning and separation of coal.

J. I. and S. I., vol. 1, p. 278. Brief description of a new coal-washer.

J. I. and S. I., vol. 2, p. 727. Description of a modified jig coal-washer.

1891.

Engr., vol. 51, p. 184, February 13. Description and elaborate drawings of a Lührig coal-washing plant in England. Gives summary of results obtained.

J. I. and S. I., vol. 1, p. 348. Description of two coal-washing plants.

J. I. and S. I., vol 2, p. 231. Brief description and discussion of two coal-washing plants.

Journal of the Society of Chemical Industry (London), vol. 10, p. 984. Description and discussion of the Lührig coal-washing system.

Lond. Eng., February 18. Brief reference to coal-washing.

Trans. Federated I. M. E., vol. 3, p. 504. Brief discussion of the crushing and washing of coal.

1892.

Am. Mfr. and Iron World, January 8. Descriptions and illustrations of coal-washing machinery.

Eng. and Min. Jour., July 2. Illustration and description of coal-washing plant in Germany.

Engr., vol. 53, p. 132. Illustration and description of coal-washing plant at Zollern, Germany. Gives considerable detail data.

J. I. and S. I., vol. 1, p. 387. Brief description and discussion of an English screening and washing plant.

J. I. and S. I., vol. 1, p. 390. Short description of a coal-washing plant in Asia Minor.

J. I. and S. I., vol. 2, p. 419. Brief mention of Stutz coal-washer.

1893.

Eng. and Min. Jour., January 28. Experiments with washing coal.

Eng. and Min. Jour., February 11. Illustration and description of Campbell coal-washing plant.

Eng. and Min. Jour., March 25. Illustration and description of washing plant.

J. I. and S. I., vol 1, p. 287. Brief description of several coal-washing plants.

J. I. and S. I., vol. 2, p. 155. Description, with good illustrations, of a Lührig coal-washing plant. Gives summary of guarantee and efficiency.

Lupton, *Mining*, p. 460. Brief description, with several illustrations of jigging coal-washers.

Trans. Federated I. M. E., vol. 6, p. 392. Description and illustration of the Lührig coal-washing system. Gives summary of costs and profits.

Trans. Federated I. M. E., vol. 7, p. 12. Brief discussion of, *ibid.*, vol. 6, p. 393 and 545.

Trans. Federated I. M. E., vol. 7, p. 156. The Baum coal-washing machinery. Gives description and illustrations.

1894.

Eng. and Min. Jour., vol. 58, p. 10, July 7. Abstract of article on English coal-washing plant.

Eng. and Min. Jour., July 28. Illustration and description of English washing plant.

J. I. and *S. I.*, vol. 1, p. 510. Brief description of several new coal-washing plants.

J. I. and S. I., vol. 2, p. 375. Brief mention of several new coal-washing plants.

Pract. Eng., vol. 9, p. 459, June 15. Brief discussion of coal-washing.

Trans. A. I. M. E., vol. 24, p. 409, 918. Comprehensive discussion of the science of jigging. Gives tables, diagrams, illustrations of apparatus, summary of laws and much valuable data.

Trans. Federated I. M. E., vol. 8, p..210, 387. Historical notes on early plans for coal-washing.

1895.

Eng. and Min. Jour., vol. 59, p. 34, January 12. Abstract of paper on theory and practice of coal-washing.

Glückauf, vol. 31, p. 631–634, 654-656. Detailed description and excellent illustrations of a new German coal-washing plant.

Fulton, *Treatise on Coke*, p. 49. Beginning of elaborate discussion of coal-washing machinery. Gives description and illustrations of Trough washer, Hartz jig, Berard's, Stutz-Stein's, Diescher's, Walburn-Swenson, Robinson's, Lührig and Dowlar's washers. Gives summary on page 88.

J. I. and S I., vol. 1, p. 79. Several references to the coal-washing industry.

J. I. and S. I., vol. 2, p. 452. Abstracts of several articles on coal-washing.

Lond. Eng., vol. 79, p. 370, May 3. General drawings and detailed description of coal-washing plant in England. Shows arrangement of all machinery in detail.

Lond. Eng., vol. 80, p. 560, December 6. General drawings, with description of an English coal-washing plant. Gives summary of results.

Lond. Eng., vol. 80, p. 626, December 12. Description and illustration of the Francon coal-washer.

Revue Universelle des Mines, p. 167. Comprehensive discussion of the Francon coal-washer. Gives valuable data.

Trans. A. I. M. E., vol. 25, p. 113. Notes on a Southern coal-washing plant. Gives extensive summary of results.

Trans. Federated I. M. E., vol. 9, p. 42. The Murton coal-washer. Gives illustrations, description, method of working and summary of costs.

Trans. Federated I. M. E., vol 11, p. 55. Elliott coal-washing plant. Gives illustrations of machine and summary of results obtained.

Trans. Federated I. M. E., vol 11, p. 647. Abstract of article on the Francon washer.

1896.

Am. Mfr. and Iron World, May 1. Historical notes on early plans for coal-washing.

Am. Mfr. and Iron World, August 7. Description and illustration of the Brookwood coal-washer.

Col. Eng., November. Lecture on coal-washing.

Col. Guard., February 14. Description and illustration of a large coal-washing plant.

Col. Guard., November 6. The Baum coal-washing apparatus

Eng. and Min. Jour., March 28. Description and illustration of Elliott coal-washer.

Eng. and Min. Jour., May 23. Brief description of a German coal-washing plant.

Eng. and Min. Jour., July 11. Utilization of waste from coal-washer.

Eng. and Min. Jour., August 8. Illustration and description of washing plant.

Eng. and Min. Jour., October 24. Illustration and description of coal-washing plant.

Eng. and Min. Jour., November 28. Illustration and description of a washing plant.

Eng. News., vol. 36, p. 395, December 17. Abstract of article on washing bituminous coal by the Lührig process.

Iron and Coal Trades' Review, June 5. The screening and washing of coal (serial, 1st part).

Iron and Coal Trades' Review, October 2. Discussion of the benefits of washing coal.

J. I. and S. I., vol. 1, p. 386. Reference is made to several coal-washers and plants.

J. I. and S. I., vol. 2, p. 343. Description of coal-washing machinery.

Lond. Eng., p. 215, February 28. Brief description of Elliott washer.

Lond. Eng., vol. 82, p. 410, October 23. Detailed description of coal-cleaning machinery at Aberamman colliery, England. Gives many dimensions.

Lond. Eng., vol. 82, p. 409, 410–418, 461–470. Elaborate drawing and description of an English coal-washing plant.

Proc. I. C. E., vol. 124, p. 509. Abstract of article on jigging.

Proc. I. C. E., vol. 124, p. 507. Abstract of article on the Francon coal-washer. Gives description and general data.

School of Mines Quarterly (New York), July. Coal-washing plant for soft coal. Gives extensive description and good illustrations.

Trans Fed. I. M. E., vol. 12, p. 244. Description and illustration of the Murton coal-washing system.

1897.

Col. Eng., June. Coal-washing in Colorado (serial).

Col. Eng., September. Description of coal-washing plant.

Col. Guard., April 30. Description of the Wunderlich coal-washer.

Col. Guard., May 28. Illustration of Spanish coal-washing plant.

Col. Guard., July 16. Washing of dusty coals; discusses methods.

Eng. and Min. Jour., July 17. Description of the Jeffrey-Robinson coal-washer.

Eng. and Min. Jour., October 2. Description and illustration of coal-washer.

Engr., vol. 63, p. 102, January 22. Description and general detail drawings of the Lührig coal-washing system. Gives summary of results.

J. I. and S. I., vol. 2, p. 366. Description of several new coal-washing machines.

J. I. and S. I., vol. 1, p. 440. Discussion of coal-washing apparatus.

J. I. and S. I., vol. 1, p. 445. Numerous references to new coal-washing plants.

Oester. Zeitsch. f. Berg u. Hüet., June 26. Illustration of Wunderlich washer.

Trans. A. S. M. E., vol. 18, p. 84, December. The washing of soft coal by the Lührig process. Gives drawings of plant, detailed description of method of operation and a large amount of valuable data.

1898.

Am. Mfr. and Iron World., March 25. History of coal-washing in Alabama.

Can. Min. Rev., August. Comparative benefits of coal-washing.

Cass. Mag., vol. 15, p. 60, November. Description and illustrations of several types of coal-washers.

Col. Guard., July 1. English coal-washing plant.

Col. Guard., August 5. Dry method of cleaning coal.

Col. Guard., September 9. French methods of coal-washing.

Col. Guard., October 28. Illustration of washers.

Eng. and Min. Jour., March 5. Waste from coal-washers.

Eng. and Min. Jour., June 11. Washing plant for anthracite waste.

J. I. and S. I., vol. 1, p. 428. Brief mention of coal-washer.

J. I. and S. I., vol. 2, p. 451. Short description of coal-washing plant.

Le Genie Civil, September 17. Discussion of a French coal-washing plant.

Mines and Min., p. 395, April. Description of the methods used and results obtained by washing Alabama coal for coke-making. Gives large number of analyses showing results accomplished.

Oester. Zeitsch. f. Berg u. Hüet., October 22. Improvements in washing machinery.

Trans. A. I. M. E., vol. 28, p. 486, December. The effect of sizing on the removal of sulphur.

Trans. I. M. E., vol. 16, p. 589. Abstract of article on the purification of coal wash water and artificial formation of shale.

Trans. I. M. E., vol. 16, p. 588. Abstract of article on the Wunderlich coal-washer. Gives summary of results.

1899.

Col. Guard., January 27. The use of jigging machines.

Col. Guard., February 10. The efficiency of coal-washing.

Col. Guard., March 3. French washing plant.

Col. Guard., October 27. The separation of coal; discusses principle involved.

Eng. News, vol 41, p. 70, February 2. Abstract of article on the effect of sizing on the removal of sulphur from coal by washing.

Eng. and Min. Jour., August 5. Illustration and description of Burnet washer.

Eng. and Min. Jour., December 16. Coal-washing plant in Montana.

Iron and Coal Trades' Review, June 23. Illustration and description of Rhymney coal-washing plant.

J. I. and S. I., vol. 1, p. 364. Brief description of some new coal-washing machines.

J. I. and S. I., vol. 2, p. 392. Brief discussion of coal-washing.

Mines and Min., p. 299, February. Discussion of the concentration of low-grade ores by means of jigs.

1900.

Eng. and Min. Jour., vol. 70, p. 94, July 28. Brief description of a Belgium coal-washing plant.

Iron and Coal Trades' Review, March 20. Illustration of washing plant.

J. I. and S. I., vol. 1, p. 343. Brief discussion of some new ideas in coal-washing apparatus.

J. I. and S. I, vol. 2, p. 484. Several references to coal-washing appliances.

Kerr, *Practical Coal Mining*, p. 407. Gives classification of methods of coal-washing, with description and illustrations of several types of washers.

Lond. Eng, vol. 90, p. 98, July 27. Brief description of the Jeffrey coal-washing plants.

Mineral Industry, vol. 9, p. 731. Discussion of ore-dressing, with several refences to coal-washing.

Smyth, *Coal and Coal Mining*, p. 292. Brief reference to washed coal.

Trans. I. M. E., vol. 21, p. 50. Brief reference to the importance of washed coal.

1901.

Col. Guard., August 16. Washing plant at a Belgian colliery.

Hughes, *Coal Mining*, p. 497. Brief discussion of coal-washing.

Jour. W Soc. of Engrs., December. The washing of soft coals by the Lührig process.

Mines and Min., September. Illustrated description of the coal-washing plant at Collinsville, Ind.

Peel, *Coal Mining*, p. 258. Brief reference to coal-washing.

1902.

Am. Mf. and Iron World, vol. 70, p. 267. Brief discussion of the Maurice coal-washer. Gives summary of results.

Coal and Metal Miners' Handbook, p. 434. Discussion of coal-washing.

Coal and Metal Miners' Pocket-Book, p. 434. Discusses theory and operation of hydraulic classifiers, with a summary of the theory of jigging on page 439.

Col. Guard., vol. 84, p. 1119. Brief reference to value of coal-washing.

Col. Guard., vol. 84, p. 1393. Brief reference to the washing of coal.

Col. Guard., vol. 84, p. 1717. Brief reference to the washing of coal, giving description of Baum washer. Gives summary of results.

Engr., vol. 74, p. 239, August 22. Brief description of German coal-cleaning plants.

Engr., vol. 74, p. 441. Illustrations and description of the coal-washing plant at the Düsseldorf Exhibition. Very complete.

Eng. and Min. Jour., September 20. Discussion, with illustrations of coal-washing plant in Kansas.

Iron and Coal Trades' Review, June 6. Illustrated description of the Campbell coal-washer.

Iron and Coal Trades' Review, November 7. The screening and washing of coal in Germany. Serial, 1st part.

Mineral Industry, vol. 11, p. 657. Brief discussion of coal-washing.

Mines and Min., p. 36, August. Discussion of the principles of coal-washing- Gives mathematical deductions of formula.

Oester. Zeitsch. f. Berg u. Hüet., December 20. Detailed description of a modern coal-washing plant in Northern Austria.

Trans. A. I. M. E., vol. 32, p. 154. Brief description of coal-washing plant in Mexico.

Trans. I. M E., vol. 23, p. 179. Description and illustrations of the Craig coal-washer, with discussion of its merits.

Trans. I. M. E., vol. 23, p. 435. Comprehensive article on the Campbell coal-washer. Gives illustrations, discussion of merits, and summary of results obtained.

1903.

Col. Guard., January 23. Illustrated description of a plant in Austria.

Col. Guard., vol. 85, p. 351. Brief reference to coal-washing.

Eng. and Min. Jour, May 9. A modern method of coal-washing. Gives drawings of the Campbell coal-washer.

Mines and Min., p. 456, May. Brief description of washing plant for Montana coal.

Mines and Min, p. 481, June. Description and illustrations of washing plant for handling anthracite culm. Drawings give general dimensions.

Mines and Min., June. Illustrates and describes the methods and machinery employed in handling and separating coal from culm banks.

Mines and Min., p. 212, December. Description and illustrations of the Stewart coal-washing system. Gives summary of costs.

Mines and Min, p. 215, December. Brief quotation from U. S. Geological Survey Bulletin on "The Manufacture of Coke."

Mines and Min., p. 228, December. Description and illustration of plant for washing Montana coal.

Richards, *Ore Dressing.* Both volumes of the above treatise are replete with data on sizing, jigging, and classification of ores.

1904.

Economical Burning of Coal Without Smoke, p. 28. Publication of the Peabody Coal Company.

Mines and Min., p. 371, March. Description and good illustrations of coal-washing plant in Indian Territory.

Mines and Min., December. Illustrated description of washing plant of the Colorado Fuel and Iron Co.

Mines and Min., December. Description of various trough and jigging washers. Gives tables and costs.

Mines and Min., December. Description and illustration of washing plant using Robinson and Stewart washers.

1905.

Cocklin, *Coal Mining*, p. 376. Several illustrations of coal-washers.

Eng and Min. Jour., vol. 80, p. 867. Discussion of shaking screens for coal-washing.

Fulton, *Coke*, p. 56. Thorough discussion, with numerous illustrations of washers. Gives results of various tests. This is the best treatment of the subject yet published.

Mines and Min., vol. 26, p. 87. Brief description of German coal-washing plant.

SUBJECT TO REVISION.

[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

The Geology and Petrography of the Goldfield Mining-District, Nevada.

BY JOHN B. HASTINGS, DENVER, COLO., AND CHARLES P. BERKEY, NEW YORK, N. Y.

(Bethlehem Meeting, February, 1906.)

I. GEOLOGICAL.*

THE reconnaissance of the Goldfield mining-district, described in this paper, was made in May and June, 1905, and, though this time was too short for a complete report, the work accomplished may serve as a basis for more thorough future research. Dr. Berkey has examined the rocks collected by myself, and I am using his classifications. As a result of further field-work, and Dr. Berkey's examination of the rocks, this paper is an elaboration and correction of my views expressed in the *Goldfield Sun*, May 12, 1905. The sketch-map, Fig. 1, illustrates the geology of the Goldfield mining-district.

Goldfield is an eruptive complex, consisting of alaskite (binary granite), hornblende-andesite, hornblende-dacite, rhyolite, pyroxene-andesite, pyroxene-dacite (sometimes containing a small quantity of olivine), quartz-felsite, olivine-pyroxene-andesite, and basalt. Considering this list to be arranged in the order of eruption, the age-sequence of the rocks conforms to Richthofen's law, formulated in 1868. From his observations in Europe and America, propylite, andesite, trachyte, rhyolite and basalt, occurring together, succeed one another. In a general way, the medium and more acidic rocks precede the most basic—a result supposed by some to have arisen from their relative position beneath the surface, and due to a rude stratification by gravity in the original cooling magma during the older history of the earth, or to the same differentiation occurring during a quiescent (molten ?) period preceding eruption, being aided by the ease with which acidic rocks, mixed with water vapors, become fusible. In effect, the more basic and less re-

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* By John B. Hastings.

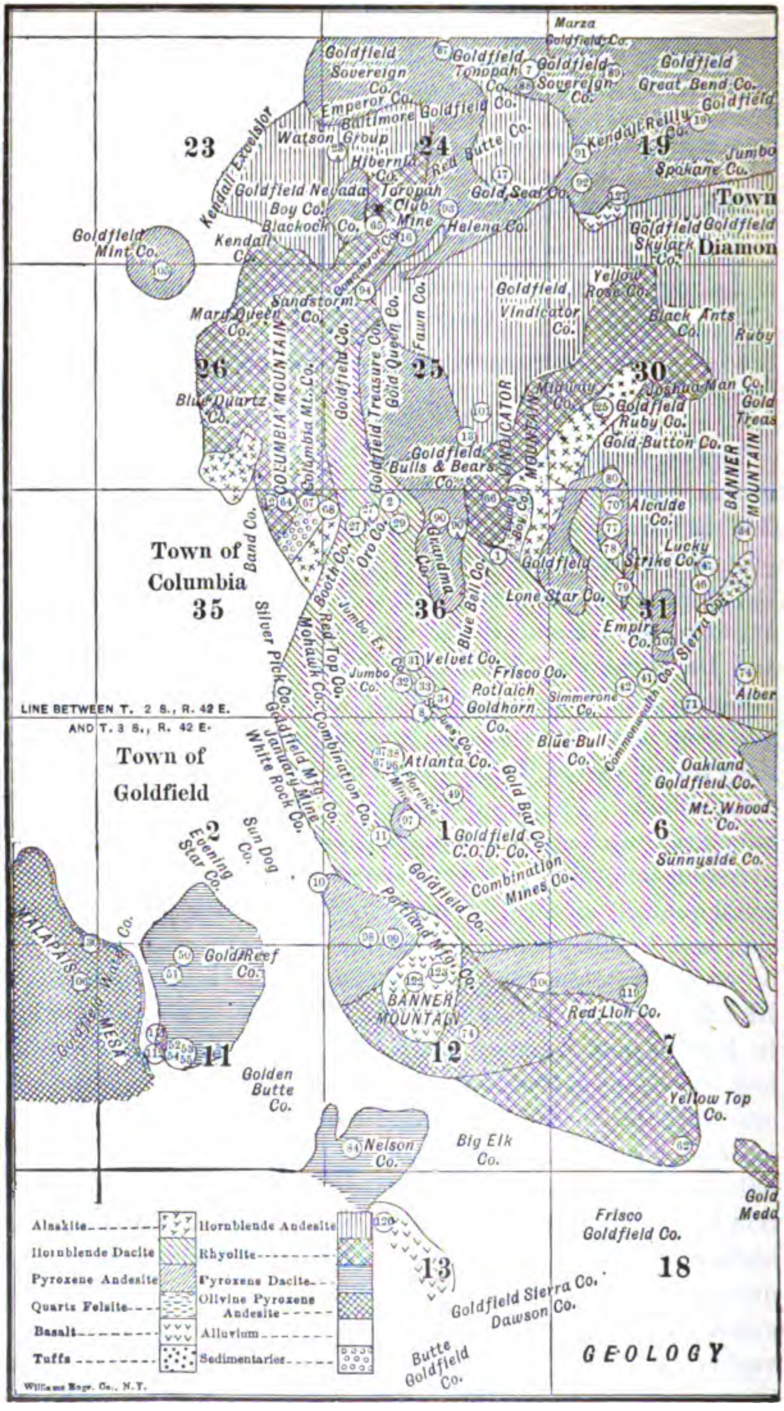
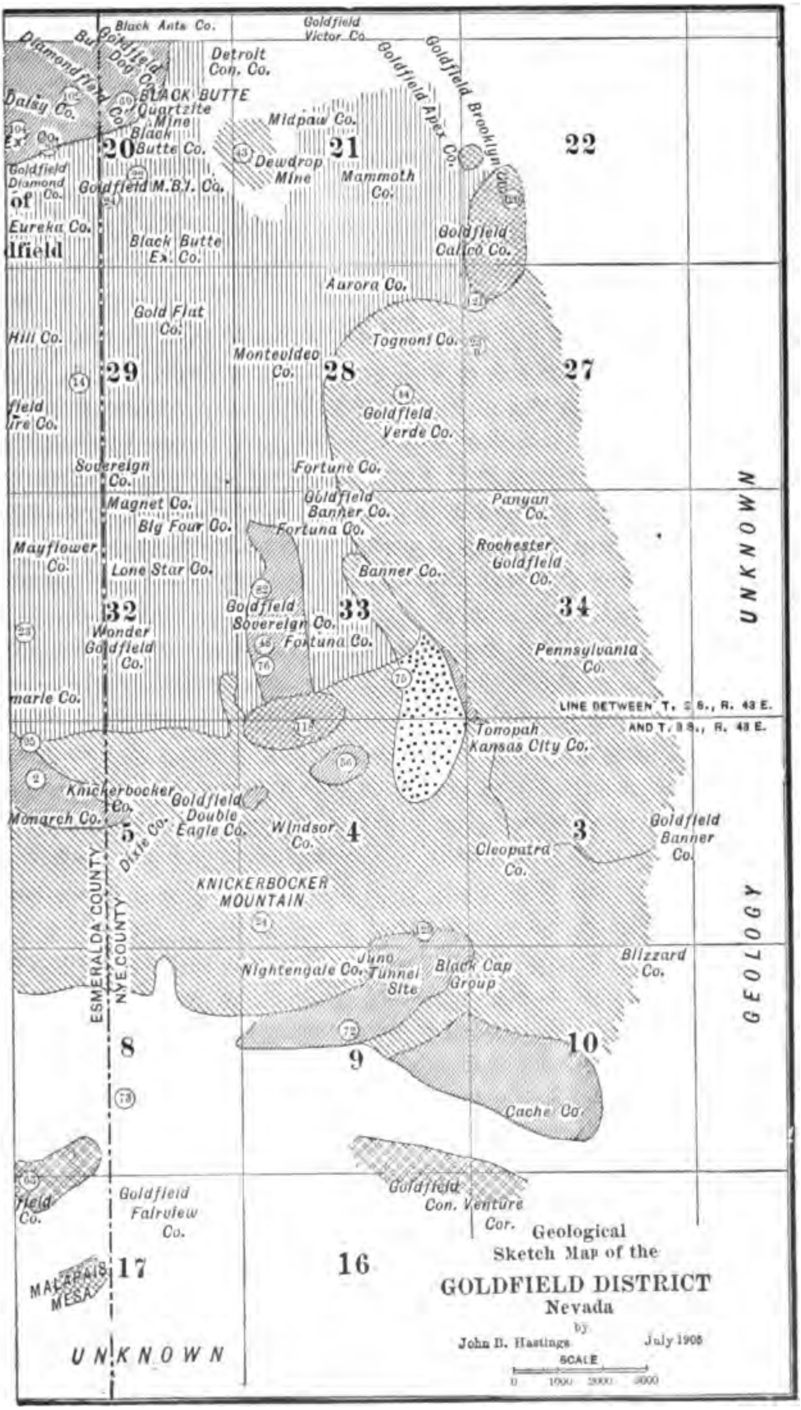


Fig. 1.—Geological Sketch-Map of



THE GOLDFIELD MINING-DISTRICT.

fractory rocks, from a smelting-standpoint, really seem to need a higher heat, or at least a more prolonged action, to bring them to the surface.

The observed occurrences of other rocks comprise: two inclusions of sedimentaries (indurated slates or shales, between alaskite and rhyolite) on Columbia and Vindicator mountains; a few very small areas of stratified tuffs, on the Tonopah Club and Desert Rose claims; a large body of tuff in Sections 4 and 33, and, possibly, in other areas of the altered zone, extending from Sections 3 to 36.

The ore-bodies occur in the hornblende-dacite and andesite of Knickerbocker mountain, in the rhyolite of Columbia and Vindicator mountains, and in pyroxene-andesite at the Quartzite mine. The whole area shows abundant remains of solfatarism, except in the rhyolite of Myers mountain, and the later pyroxene-andesite, olivine-andesite, pyroxene-dacite, felsite and basalt.

There is extreme silicification of the andesite, dacite and rhyolite along fractures generally northerly and southerly, but also easterly and westerly, forming reefs from 2 to 40 ft. wide, and, in the aggregate, possibly 40 miles long. These zones contain a vast quantity of material resembling hard sugar-quartz, but everywhere interspersed with a greater quantity of the original rock, still dimly showing its porphyritic character. Silicification, less intense, has occurred over large undefined areas.

The silicified reefs are usually barren, but the rich shipping-ores have been found intimately associated with them. My knowledge is insufficient to enable me to say much of the ore-deposits. In the Florence, Quartzite, January mines, and in portions of the Combination mine, it appears as if the areas opened were on primary rich vein-fissures, which are rather small, except where they have been enriched.

In the Sandstorm mine, the rich ore follows a pre-existing northerly and southerly siliceous reef, along which the ore occurs at intersections of easterly and westerly fissures. While distinct brecciation was not observable at the crossings, in one instance the reef was faulted a distance of 6 ft. by the later fissure. The main ore-bodies were in the siliceous reef, the diminishing values extending for 25 ft. along the cross-fissures. The enclosing rock is rhyolite.

The Florence, Combination, and January veins, in the southerly area, striking NW. and dipping east, are crossed by other simultaneously mineralized fissures, striking NE. and dipping NW., into which the ore is deflected. The northwest fissuring continues, and the ore in the cross-fissures may only follow them for a certain extent, to be picked up again later in the parent fissures. The enclosing rock is dacite.

The Quartzite mine is the representative fissure in the northern end of the district. The vein strikes N. 20° W., dips westerly, and is about 5 ft. wide as stoped. A characteristic piece of the enclosing rock from the dump was pyroxene-andesite, having the same blue color and appearance as the southern mineral-bearing dacite, but lacked the quartzes. The brownish pyroxene-andesite, west of the quartzite, in Sections 19 and 24, is later than the silicified zones, peaks of the latter, too small to be mapped, outcropping like islands in the andesite-flow.

In the Florence, Combination and Quartzite, there are cross-fissures younger than the mineralization, which have faulted the veins, and this may be generally expected from the more recent vulcanism.

The tuffs on the Tonopah Club and Desert Rose, cursorily alluded to before, are in shallow detached bodies, occurring as shaly deposits on the present surface, and surviving only in a few depressions. At the Tonopah Club mine several of these small deposits, from 2 to 10 ft. deep, are crossed by the vein-fissure, with a slight faulting. The horizontal tuffs, with bedding-planes at right angles to the fissure, have been permeated and mineralized by the ascending solutions.

Since the beginning of the last century, attention has been called to the large amount of water and its vapor accompanying vulcanism; also to the fact that, after the cessation of rock-extrusion, hot waters still make a way to the surface, though forced from the body of the inactive eruptive to its contact with neighboring rocks and other lines of least resistance, such as faults, fractures and permeable limestones, etc. These waters, saline or vadose, were supposed to reach the volcanic rocks from the sea or from the earth's surface. It has been generally considered that, by gravity and capillarity, the waters would descend to the molten areas through saturated fissures and rocks, which, in turn, seemed to afford an easy passage to the surface. On the other hand, some observers proclaim it impossible for water to travel against the pressure of vapors which would be created in rocks surrounding the deep scene of volcanic action.

It has been pointed out that but little capillary or other water is found in deep mines. In discussions on this subject I do not remember to have seen mentioned that fissures, later than the veins, now carry the surface water. It is usual, in mining, to find the veins dry, and some cross-fissures flooded. Mine after mine has been cited as dry in its lower levels, and even the Rand mines are said to be making very little new water. Apart from local unfitness, I should imagine the center of such a synclinal, as the Rand, to be an ideal spot for artesian water. However, the chief fact seems to remain in prominence, namely, that there is less water in underground circulation than was formerly supposed.

The most recent theory predicates the great central mass of the earth, beginning 190 miles below the surface (equaling 0.975 of its whole bulk), to be a core of compressed gases, similar to the sun's central nucleus; only, in the case of the earth, which has four times the density of the sun, these gases, on account of their specific gravity and resistance to deformation, must be nearly as heavy and as rigid as steel. As an addendum to this premise, water of volcanoes is then presumptively evolved from these gases, and escape during a slight relief from the pressure which accompanies igneous phenomena.

Whatever may be the origin of volcanic waters and associated vapors and gases, their passage upwards, under great heat and pressure, thoroughly permeating large bodies of molten eruptives, would furnish the most ideal solvent in the best source of supply imaginable.

There is no proper drainage-system in Nevada. None of the rivers reach the ocean; all sink, either in the channel itself or in the lakes in the great valleys. Probably an important migration of vadose water progresses underground, which, in the past, has been interrupted by newly-formed volcanic necks. These waters became heated, joined magmatic waters, and rose to the surface; hence, as the rocks cooled and magmatic waters ceased, the springs dried up. Since there has been a succession of eruptive actions in Goldfield, there is also a succession of solfatarism. Perhaps more than ordinarily, the Goldfield deposits suggest the derivation of the ores from ascending hot magmatic and vadose waters.

II. Topography.*

The Goldfield district has the erratic topography of a recent volcanic area, modified but slightly by erosion, the silicified portions forming small peaks by their resistance to the elements.

Columbia mountain, while composed largely on its south end of alaskite, as shown by the Columbia Mountain tunnel, is a rhyolitic neck; Vindicator mountain also is a rhyolitic neck.

Banner mountain, which may also be a volcanic peak, is possibly the product of erosion, since the summit is a mass of hard silicified andesite, and the surrounding basal plain a soft andesite and dacite.

Knickerbocker mountain is a great volcanic cone, from which the dacites have flowed northwesterly and easterly, partly covering the older hornblende-andesite.

Table mountain in Section 9, on which the Black Cap group and the Juno tunnel-site are located, is a basaltic neck, with a later flow of pyroxene-andesite, the hard andesite protecting the soft, underlying, altered dacite, which forms a ring around the obtruding cone.

In Sections 12, 13 and 14 is another table mountain protected by dacite and basalt, the two effusions exposed side by side.

Myers mountain, another volcanic neck, at first extruded rhyolite, in Section 7. This rhyolite is more basic than and different, macroscopically, from rhyolites of Columbia and Vindicator mountains. Olivine-pyroxene-andesite (Section 12) followed the rhyolite, then pyroxene-andesite (Section 1), and, finally, basalt (Section 12), now crowning the summit.

The Malapais mesa, west of Goldfield, extending 4 miles northerly and 4 miles southerly, and as much as 4 miles wide, is a marked example of a table mountain protected by a hard cap. Here lake-beds and tuffs were covered with a thin bed

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* By John B. Hastings.

(from 10 to 50 ft.) of quartz-felsite; the felsite itself was covered soon after by a similar sheet of olivine-pyroxene-andesite.

The pink felsite and black andesite are a marked contrast; the former is a fine example of igneo-aqueous fusion, with steam vesicles up to a diameter of 5 ft.; it may have been an underwater flow. The andesite is comparatively solid. These rocks seem like rivals, and one is struck with the tenacity with which the darker basic rock has so completely covered the lighter acidic rock. The depths of the flows vary, but not much so, one from another; the edges are exposed for many miles on top of the bluff.

A somewhat interesting duplication occurs in Section 11, on the south end of the Wild Horse claim, which, at first, seemed suggestive of a downward faulting on the mesa scarp. This occurrence is explained by Fig. 2. The augite-dacite, *F*, has a slight superficial resemblance to the felsite, *B*, and the olivine-pyroxene-andesite, *E*, to the olivine-pyroxene-andesite, *A*. This last rock preserves its marked characteristics for miles, perhaps the most noticeable being the iron-stained olivines. I could not determine whether *E* and *F* emanated southerly from under the mesa; they disappeared northerly under the wash. Perhaps the olivine-pyroxene-augite occurring in the wells of the Goldfield Brewery & Los Angeles Co. are connected with *E*. There is another nearby outcrop of olivine-pyroxene-andesite, a fine-grained rock, between the Water Tank butte and Mesa (Section 2). The dacite, *F*, is traceable in detached areas to and beyond the summit in Section 14, and east of the Lida road.

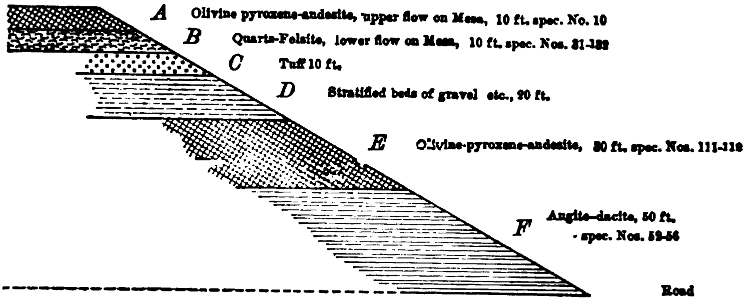
A Olivine pyroxene-andesite, upper flow on Mesa, 10 ft. spec. No. 10
B Quartz-Felsite, lower flow on Mesa, 10 ft. spec. Nos. 81-122
C Tuff 10 ft.
D Stratified beds of gravel etc., 20 ft.
E Olivine-pyroxene-andesite, 30 ft. spec. Nos. 111-118
F Augite-dacite, 50 ft. spec. Nos. 52-56
Road

FIG. 2.—IDEALIZED GEOLOGICAL SECTION ON THE SOUTH END OF WHITE HORSE CLAIM, SEC. 11

The mountains in Sections 27 and 34, on the east boundary of the district, are composed of a coarse typical andesite with quartz phenocrysts, that is,—hornblende-dacite much younger than the dacites of Knickerbocker mountain.

Mapped with the dacites of Knickerbocker mountain are fine-grained altered areas, the composition of which I was unable to determine.

III. PETROGRAPHY.*

The chief object of the microscopic study of the specimens of rock, gathered by Mr. Hastings, has been to identify them and suggest relationships as an aid to field-mapping, and the interpretation of geological structure. At the same time the characteristic secondary changes in the rocks, and the relationships of these to the ores, have been constantly in mind, with a view to the bearing upon the genesis of the ore-deposits of the district. Mr. Hastings, in the first part of this paper, has given the field-relationships, and makes the appropriate applications of such suggestions as a microscopic study of the rocks seems to warrant. On account of the interest felt in the district, and the rather unusual series of rocks represented at Goldfield, it seems advisable to add more detailed notes on the petrography of the area. The only notes published, so far as I know, are those of Mr. J. E. Spurr.[1] For the material and permission to use it in this way, I am indebted to Mr Hastings.

The specimens of rock and ore have been collected in a systematic study of the Goldfield district and vicinity. A greater number of these specimens necessarily represent the more obscure or less easily identified of the outcrops, together with the more complex structural areas. Altogether, however, the set must represent quite fully the range of rock-types of the district, and the comparative number of specimens in each type must indicate roughly their relative importance either areally, structurally, or economically.

The list of rock-types[2] includes,—(1), felsites, rhyolites, trachy-andesites, dacites, andesites, and basalts, representing felsitic and porphyritic varieties; (2), a granite as the only granitoid variety, except two or three cases of granular holocrystalline andesites and basalts that may, with equal propriety, classify as diorite and dolerite, so far as this examination applies; (3), rhyolitic, dacitic, and andesitic tuffs among the pyroclastics; and (4), a carbonaceous quartz-slate as a representative of hydroclastics.

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* By Charles P. Berkey.

[1] *Bulletin No.* 260, *U. S. Geological Survey*, p. 133 (1905). *Bulletin No.* 225, *U. S. Geological Survey*, pp. 118–119 (1903).

[2] A similarity to the rocks of Tonopah, Nevada, is readily noted. The chief types described by Spurr for that area are: rhyolite, andesite, and dacite. *Bulletin No.* 219, *U. S. Geological Survey*, p. 12-15, 1903. *Professional Paper No.* 42, *U. S. Geological Survey*, p. 30–71.

Andesites, the dominant type, include 78 specimens, or more than half of the total number. Next, numerically, is dacite, of which there are 21 specimens. Then follows the rhyolites to the number of 8 specimens, and, finally, basalt, of which only 3 in the original identification list were so classed, although there are 5 more, included with the andesites, that carry so much olivine and are of such strong basic affinities that they could, with equal reason, be included with the basalts. No other type occurs in large numbers.

Silicified, indurated rocks include the specimens of ores and several others, and are treated separately.

In the following list the numbers of the specimen corresponds to the numbers on the map, Fig. 1, and are the serial numbers preserved with them and the corresponding thin sections in the Petrographic Laboratory of Columbia University, New York, N. Y., and by Mr. Hastings at Denver, Colo.

Granite, No. 1. The rock is very coarse-grained, with an unusually large amount of quartz, which carries numerous inclusions, largely in trains, some passing from one grain to another. Cracks also extend across in a similar manner, showing, on the whole, considerable crushing and recementing. The rock has no other gneissic characters. Orthoclase is abundant and uniformly clouded with kaolin-alteration, making it nearly opaque. There is a little albite. Iron oxide, hematite, gives a brown stain in a few spots. No identifiable dark mineral is seen in the slide. The rock is an exceptionally acid variety of granite, and is a fair representative of the alaskite of Spurr.

Rhyolite (Nos. 62 to 68). Most of these rocks show a characteristic flowage-structure, and a spherulitic or mottled, devitrified ground-mass. Quartz is abundant, both in the ground-mass and in rounded or angular phenocrysts, sometimes giving a decided porphyritic aspect. Resorption of the phenocrysts is marked. Biotite is the chief dark mineral. Orthoclase predominates over plagioclase. Magnetite is abundant in one or two specimens. The dark minerals are not conspicuous. Scapolite is developed to a considerable extent in 3 specimens, taking, in part, the place of original feldspars. A mottling of the rock, due to silicification, is also noticeable. No attempt has been made to indicate the field-relationships or the history by a differentiation into rhyolites and quartz-porphyries.

Felsite (Nos. 129, 130). There are two rocks of acid character, with glassy and devitrified ground-mass, showing flowage, that are called felsites, chiefly because of inability to decide whether rhyolitic or dacitic affinities prevail. Quartz is the only abundant determinable mineral, although both orthoclase and a plagioclase are present. Biotite and pyroxene are also present. The two rocks are not alike, however, and evidently do not belong to the same flow. They are regarded as a sub-type between the characteristic rhyolites of the district and the dacites proper, both of which are well recognized.

Dacite (Nos. 27 to 61). This group shows considerable variation. There are no less than 8 sub-varieties or sub-groups, based upon minor specific differences among them, as seen in the microscope. One specimen, at least, has about an equal claim to classification with the rhyolites, and from this they represent many different mixtures and proportions to the other extreme, where one specimen of decidedly basic character, and in which olivine and augite are prominent constituents, can, with even better propriety, be placed with the quartz-basalts. The ground-mass of these rocks is either glassy to felsitic, or spherulitic and mottled, or pilitic. Flowage is a prevailing structure, specially marked in those of pilitic habit, and is well-developed even in the more crystalline varieties. Nearly all are porphyritic, although the phenocrysts are mostly very small, or, at best, inconspicuous, except as seen in thin section. Plagioclase is abundant as phenocrysts. The medium types all carry biotite in considerable amount as the chief dark constituent (Nos. 28, 29, 30). Hornblende is present with biotite, and in Nos. 31, 32, 41, 42 and 35 it becomes the chief ferro-magnesian constituent, and is developed in fine idiomorphic individuals. Most of those, low in biotite and hornblende, carry augite, showing the same range as is seen in the group of andesites proper, and the extreme in this direction is reached in the specimens before noted, in which olivine also appears. Therefore, as outlined above, the series, in which quartz is a prominent constituent, exhibits the complete range from rhyolite and quartz-felsite, through mica-dacites, hornblende-dacites, augite-dacites, to quartz-basalts.

Trachy-Andesite (3 specimens). There are no true trachytes. One specimen in particular (No. 94), and two others to less-marked degree, are decidedly more acid than the average andesite, and have a trachitoid structure. The relative abundance of the different feldspars is in question. But the relative position of these rocks, among the others of the whole series, is best indicated by the above name.

Andesites (78 specimens, subdivided below). The andesitic rocks are in greatest number, surpassing all other types combined, and exhibiting the greatest number of minor differences among themselves, which indicate separable structural field-units of flows, sheets or dikes. The more basic varieties are the most perfectly preserved rocks of the district. The large number involved, and the evident importance of the group, make it advisable to subdivide into specific mineralogical varieties. Porphyritic development is prevalent, though often on a microscopic scale. Those most notable are referred to in the geology of the district as andesite-porphyries. In the present discussion, however, those textural variations are largely ignored in the effort to indicate the mineralogical relationships. They cover the entire range from trachy-andesites to the basalts proper.

Mica-Andesite (3 specimens). Biotite is the chief ferro-magnesian mineral. Hornblende is either negligible or is present in subordinate amount. Chlorite is a common secondary (Nos. 3, 4, 17). In several much altered specimens the ferro-magnesian mineral is destroyed. Some of them probably belong in this group.

Hornblende-Andesite (11 specimens). Hornblende is the chief dark mineral (Nos. 5, 19, 20, 26), occurring abundantly as phenocrysts with resorbed borders, and frequently attacked by chloritic alteration. Plagioclase is, however, the chief idiomorphic mineral, sometimes showing exceptional zonal growth and giving a marked porphyritic texture (Nos. 20, 19). Biotite is usually present in minor amount. The ground-mass is mottled or exceedingly fine felsitic or pilitic in texture. Occasionally, there is excessive alteration and induration of the whole rock (No. 45), and the structure and appearance of the product is precisely the same as specimens of ore. Iron oxide and calcite are common secondary products. One rock included here is heavily impregnated with iron oxide in small grains or specks that are so persistent and uniformly distributed as to suggest simple oxidation of a pyrite-rock. It is otherwise also much modified in composition by the usual weathering products, so that nothing but these and a few structural outlines remain to indicate its relationships (No. 23). The group, in part, include rocks that carry little dark mineral and are of acid character. A great number are of medium andesitic composition.

Pyroxene-Andesite (augite-andesite), (41 specimens). By far the greater number of andesites carry pyroxene. Common augite is the prevailing species. There are 41 rocks of this class, exclusive of those also carrying olivine, which are discussed separately; 14 specimens have little pyroxene, or, indeed, any other ferro-magnesian constituent. A few of them are among the most acid of the andesite group. As a rule, they have a fine pilitic ground-mass; they usually show flowage, and a porphyritic texture prevails. Resorption of the phenocrysts and zonal growth are almost constant characters; 18 have a trachytoid structure, with chiefly lath plagioclase instead of orthoclase in the ground-mass; 4 rocks (Nos. 88, 86, 83, 76) have biotite, in addition to augite, as a dark constituent. Hornblende is the additional basic mineral in 8 specimens, though it is abundant in only 2 (Nos. 16 and 85), and there is an occasional grain in many others; 4 are very strongly porphyritic, giving a strikingly granular aspect to the ground-mass, which, with higher magnification, exhibits multitudes of stout pyroxene rods. This variety is also the extreme in basicity of the simple pyroxene-andesite group (Nos. 72, 73, 74). Two specimens (Nos. 87 and 24) have a dense, stony, perhaps devitrified, ground-mass, giving a distinct structural variety. One (No. 98) has zonal growth of the feldspars and pyroxenes developed to an extraordinary degree—some of them also marking resorption stages. One specimen (No. 12) is distinctly fragmental in its larger units, but is considered a flowage breccia rather than a tuff. As a group, the augite-andesites are of great variety in minor characters, and represent numerous different field-units.

Hypersthene-Andesites. In 3 specimens hypersthene occurs as an essential constituent, in addition to augite and some hornblende (Nos. 92, 100, 105). They are not all of the same structural type.

Olivine-Bearing Pyroxene-Andesite (20 specimens). This whole sub-group carries olivine in addition to augite. Hornblende and biotite are absent, except rarely. The set of rocks classified here varies from very little olivine (which is true of 4 specimens) to an equal number at the other extreme, where it becomes the chief basic constituent, and where the general basic composition so nearly balances the feldspathic component that they may, with equal propriety, be included with the basalts. In a large majority of the numbers, however, the light-colored, leucocratic minerals are in excess of the melanocratics. The type is, therefore, of considerable abundance in the district. Labradorite is the abundant feldspar, but anorthite appears in the most basic. Three (3) specimens show diabasic structural tendency. One (No. 116) is also rather coarse-grained for this group, and therefore is of dolerite or diabase affinities (No. 125). These rocks are, for the most part, strongly porphyritic. They are not so prominently modified by alteration as many of the more acid groups. They are not indurated, and in a large number the olivines are still very fresh. Two of the specimens have a notably granular ground-mass (No. 113), due to pyroxene of the second generation. A fine pilitic or trachytoid ground-mass is more common. One (No. 127) shows marked flowage-structure and zonal growth of the phenocrysts to an unusual degree—16 stages appearing on one feldspar. All of the constituents occur as phenocrysts. Magnetite is very abundant in some cases.

Quartz-Basalt.—One of the most basic of the above series (No. 115) carries quartz phenocrysts as a prominent constituent. Olivine is plentiful and augite is very abundant,—both together, at least, equalling the feldspars in the rock. The quartz occurs in large grains, showing resorption, and surrounded by a mass of granules and columns of augite resembling the Lassen's Peak quartz-basalt, described by Diller. The rock forms the basic limit of the quartz-bearing porphyries of the district, already mentioned under the dacites.

Basalt (3 specimens).—All are olivine basalts of the same general character as the most basic described under the olivine-bearing pyroxene-andesites above. These are still more basic (Nos. 122, 123, 124). Olivine occurs in the ground-mass and as phenocrysts. Much of the augite is granular or micro-idiomorphic in the ground-mass. In relative abundance the constituents are augite, plagioclase, olivine, magnetite. The rocks, which form the basic end of the series at Goldfield, are fresh, the olivines showing staining only along the cracks.

Alteration-Varieties.—A few of the specimens show unusual or exceptionally complete alteration. No. 7 was originally an olivine-bearing augite-andesite. The traces of original structure are still so well preserved that the zonal growth of former feldspar areas can be seen. But the rock is now largely composed of a very feebly porlarizing substance, so feeble in places as to require a sensitive tint to detect the change, and this has taken the place not only of the feldspar and olivine, but of any other constituent. It is regarded as chiefly serpentine. The rock is a pseudomorph throughout. Three of the rocks, and, to a lesser degree, a few others, have developed scapolite. They are types of dacitic affinities where determinable. Pyrite is abundant in them, and secondary quartz is in large amount in them. Scapolite has formed at the expense of the feldspar. Traces of original biotite and hornblende occur, and magnetite is the only prominent original mineral left, except an occasional quartz phenocryst. A good many of the slides show silicification. The mottled quartz-bespattered ground-mass, so often seen in the more acid and more altered varieties, is doubtless due to this process. It is a common condition in these rocks, and is especially marked in the ores and in those specimens heavily charged with pyrite. Silicification is the most characteristic alteration effect seen in the rocks of the district.

Volcanic Ash, Tuff.—Several specimens are extremely fine-grained, and lack all the structures that are so persistent in the other rocks. They are evidently much altered also, which adds to the uncertainty of their identification. The coarser ones are more satisfactory, and are certainly tuffs. The finer ones are called volcanic ash (Nos. 133–137),

Shale, or Slate.—Two specimens (Nos. 140 and 141) are very uniformly granular, black, very fine-grained, in which quartz, sometimes interlocking, can be identified. Besides, there are multitudes of uniformly distributed black specks, in part, perhaps iron oxide, but, in part, thought to be carbonaceous matter. Small quartz-veinlets abound, especially in No. 140. The rock, a sedimentary one, is a silicified carbonaceous shale, and occurs as an inclusion in one of the trachy-andesites.

Ores.—Not more than 10 of the specimens are ores. They are all quartzose. The interlocking-grains are small, prevailingly of microscopic size. In some specimens, all original structures are obliterated in the process of silicification and mineralization that they have endured. In a few, however, there are satisfactory traces of original structures and minerals,—such as original phenocrysts,—that prove the igneous character of the original rock. The forms of the phenocrysts have persisted after everything else has been lost. There is no doubt in these cases that the ores are essentially silicified porphyry, and that the mineralization has accompanied silicification. Scapolite occurs in some of these cases. A few show previous crushing, the traces of brecciation being still preserved. Therefore, the silicification probably follows these crush-zones through the formations. Hematite (No. 138) occasionally holds the place of original pyrite. But in the best slides 4 metallic minerals occur—all perfectly fresh,—gold, pyrite, a massive or granular reddish-bronze, dark, metallic mineral (unidentified), and a whitish-gray columnar or acicular metallic mineral, probably bismuthinite. There are strong tests for bismuth from fragments of the ore, and it is thought that both the last two minerals (No. 40) carry that element. The metallics are promiscuously distributed through the siliceous matrix, and, in the same manner, through and among each other. Doubtless, they were all formed in the process that involved the silicification of the rock, and, in these cases at least, they have suffered little change.

IV. List of Specimens.*

The following list of rock-specimens gives the specific localities and the identification; the numbers correspond to those on the map, Fig. 1.

1. S. 85 E., 250 ft. from NW. cor. Examiner, Section 36. Granite.
2. N. 20 E., 300 ft. from S. side center Huntch Bell, No. 18, Section 5. Felsitic andesite.
3. Half-way between Banner and Knickerbocker mountains, Section 32. Mica-andesite.
4. A piece from near the flagstaff on Banner mountain, as little altered as could be found, Section 31. Indurated mica-andesite.
5. Butte 250 ft. SW. of SW. cor. of Blind Ledge, Section 33. Hornblende-andesite.
6. Butte 1,200 ft. S. of ¼ cor. to Sections 4–33, Section 4. Andesite.
7. Fine-grained altered rock from shaft back of hill on S. end of Jumbo, Section 1. Andesite.
8. Float from St. Ives, probably came out of workings S. of shaft, Section 36. Altered andesite.
9. Dump about 800 ft. S. (?) of Portand Mining Co.'s shaft, Section 12. Olivine-andesite.
10. Butte adjoining W. side center Gold Coin, Section 2. Pyroxene-andesite.
11. Rustler Fraction W. side center, Section 1. Andesite.
12. Breccia from Piedmont Fraction ; this outcrops at foot of hill below the rhyolite, Section 35. Andesite flowage-breccia.
13. Gold Standard discovery, Section 25. Andesite.
14. Ridge at W. side cor. Gold Watch, freshest piece to be found, Section 29. Felsitic andesite, scapolite rock.
15. Little E. of N. side cor. Utah, Section 24. Andesite.
16. Tonapah Club, SE. cor., Section 24. Pyroxenic hornblende-andesite.
17. N. 10° W., 100 ft. from Belmont Queen discovery, Section 24. Mica-andesite.
18. Oakes discovery, Section 24. Andesite.
19. Half-way between Victor and Great Bend, Section 19. Andesite.
20. Between Diamondfield and the Black Butte claim, Section 20. Andesite.
21. Outcrop near Nye and Esmeralda Co.'s boundary stake, on road to Diamondfield, Section 20. Andesite.
22. 200 ft. S. of SW. cor. of Black Butte, Section 20. Andesite.
23. N. 65° E., 140 ft. from Calico discovery, Section 22, the freshest piece to be found in a large area. Andesite, badly weathered.
24. Dike on Willows claim, Section 27. Andesite with glassy ground-mass.
25. 100 ft. NE. from SE. cor. Hesperion, Section 30. Trachyte tuff, probably.
26. Knickerbocker mountain, exact location lost, Section 5. Indurated andesite.
27. Oro Goldfield shaft dump, Section 36. Dacite-porphyry.
28. Same, a little away from the shaft. Dacite-porphyry.
29. Same, from this vicinity, Section 36. Dacite-porphyry.
30. From low hill near NW. cor. of St. Louis. Dacite-porphyry.

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* Collected by Mr. Hastings and determined by Dr. Berkey.

31, 32. Jumbo Ex. dump, Section 36. Dacite-porphyry.

33, 34. From open cut N. of St. Ives shaft, Section 36. Dacite-porphyry.

35. Knickerbocker mountain summit, Section 4. Dacite-porphyry, indurated

36. Typical sample of the country-rock carrying the veins. Dacite-porphyry.

37. Florence rock from the dump, Section 1. Altered dacite, scapolite rock.

38. Ditto, heavily silicified, Section 1. Indurated dacite, ore.

39. Rich mill-rock, Florence. Indurated dacite, ore.

40. Florence ore.

41. About 300 ft. E. of Minnevada tunnel, Section 31. Dacite-porphyry.

42. Ditto, 200 ft. E. of tunnel. Dacite-porphpry with pyroxene.

43. Dewdrop shaft, Section 21. Dacite.

44. Gold Fountain, SE. cor., Section 20. Hornblende-dacite-porphyry.

45. Huntch Bell, S. side center, Section 5. A much-altered rock, either andesite or dacite.

46. NE. cor Midway Fraction, Section 31. Dacite.

47. Ditto, from N. end of flow. Dacite.

48. New York No. 1 discovery, Section 33. Silicified porphyry.

49. 500 ft. SW. of SW. cor. Union Jack, Section 1. Silicified and scapolitic rock.

50, 51. Butte, 1 mile S. of town, Section 11. Dacite-porphyry.

52. Wild Horse claim, S. end, lower flow butting against mesa, Section 11. Dacite.

53, 54. Wild Horse claim, S. end, lower flow butting against mesa, Section 11. Olivine-bearing pyroxene-dacite.

55, 56. Same as the last three, but east of the road. Dacite-porphyry.

57, 58. Regarded as the same rock as No. 52, from bluff east of Lida road, Section 14. Dacite.

59. Detached area S. of No. 59. Dacite.

60. Top part of No. 57 flow. Olivine-bearing pyroxene-dacite.

61. Valley View—Eclipse claims, from top of the Table mountain on which these claims are situate, Section 12. Dacite.

62. Meda claim, Section 7. Spherulitic rhyolite-porphyry.

63. Cor. to Sections 7, 8, 17, 18, Section 17. Rhyolite.

64. West slope of Columbia mountain. Rhyolite.

65. SE. cor. Desert Rose, No. 1, the rock with abundant quartzes E. of Sandstorm, Section 24. Rhyolite.

66. Lucky Boy amended discovery ; the slates are 125 ft. wide, and west of them this rock outcrops, Section 36. Rhyolite.

67, 68. From top of Columbia mountain. Rhyolite.

69. Quartzite shaft dump, Section 20. Pyroxene-andesite.

70. Alhambra, S. side center, Section 31. Pyroxene-andesite.

71. Just E. of intersection of Commonwealth and N. Y. side line, Section 31. Pyroxene-andesite.

72. 600 ft. SE. of NE. cor. Ida May, Section 9. Pyroxene-andesite.

73. Grasshopper Nos. 1 and 2, 50 ft. E. of E. and W. side center, Section 8. Pyroxene-andesite.

74. 75 ft. W. from N. side center Huntch Bell, No. 9, Section 31. Pyroxene-andesite.

75. Chicago, SW. cor., Section 33. Pyroxene-andesite.

76. N. Y. No. 1 discovery shaft, Section 33. Pyroxene-andesite.

77, 78. True Bell, W. side center, Section 31. Pyroxene-andesite.

79. E. side center Lady June, Section 31. Pyroxene-andesite, chloritic.

80. 50 ft. E. of SW. cor. of Fraction claim at foot of east slope of Vindicator mountain, Section 30. Pyroxene-andesite.

81. NE. cor. Gold Standard, Section 25. Pyroxene-andesite.

82. N. Y. No. 2, W. side center, Section 33. Pyroxene-andesite.

83. S. 20° E. 200 ft. from SW. and SE. corners Elizabeth and Jack Rabbit Fraction, Section 31. Pyroxene-andesite.

84. Oakes discovery shaft, Section 24. Pyroxene-andesite.

85. 200 ft. SW. of SW. cor. Adams, Section 25. Pyroxene-andesite.

86. Blackrock discovery, Section 24. Pyroxene-andesite.

87. Sections 13–24. Pyroxene-andesite.

88. Cloudy day dike? from shaft, Section 24. Pyroxene-andesite.

89. Red Butte, NE. cor., Section 19. Pyroxene-andesite.

90. From hummock east of low hill near NW. cor. of St. Louis, Section 36. Pyroxene-andesite.

91. N. 70° E. from SE. cor. Red Butte, Section 19. Pyroxene-andesite.

92. Athabasca, E. side cor., Section 19. Pyroxene (hypersthene)-andesite.

93. Autumn discovery, Section 24. Pyroxene-andesite.

94. Butte near Adams shaft, Section 25. Pyroxene-trachy-andesite.

95. S. 64° W., 100 ft. from NW. cor. Huntch Bell, No. 3, Section 5. Pyroxene-andesite.

96. Area close to Florence shaft on the east, Section 1. Pyroxene-andesite.

97. Rustler Fraction, N. 30° E. from E. side center, Section 1. Pyroxene-andesite.

98, 99. From hill west of Myers peak, Section 1. Pyroxene-andesite.

100. Red Lion boundary, Section 12. Hypersthene-andesite.

101. Location unknown. Pyroxene-andesite.

102. 100 ft. E. of S. side cor., Section 20. Pyroxene-andesite.

103. Top of bluff on summit, east of Lida road, Section 14. Pyroxene-andesite.

104. Summit of butte, south of Blue Bird, Daisy No. 2, and 3 Friends Fraction, and west of Black Butte, Section 20. Pyroxene-andesite.

105. Detached dome west of Tonopah road, Gold Leaf discovery, Section 26. Hypersthene-andesite.

106, 107, 108. Upper flow on mesa west and southwest of town, Section 11. Olivine-bearing pyroxene-andesite.

109. Top of butte where tanks of Goldfield Water Co. are situated, Section 2. Olivine-bearing pyroxene-andesite.

110. Upper flow on mesa at head of gulch at Wild Horse claim, A of Fig. 1, Section 11. Olivine-bearing pyroxene-andesite.

111, 112. E. of Fig. 1, south end Wild Horse claim, Section 11. Olivine-bearing pyroxene-andesite.

113. From behind butte on which water-tank is situated, at mouth of gulch west of town. Dike? Section 10. Olivine-bearing pyroxene-andesite.

114. Goldfield Brewery well, Section 3. Olivine-bearing pyroxene-andesite.

115. Well at Los Angeles Co.'s mill west of town, Section 2. Quartz-basalt.

116. Fifty-foot well, S. 10 E., 660 ft. from Goldfield Hospital, Section 2. Olivine-bearing pyroxene-andesite.

117. Area, Section 12. Olivine-bearing pyroxene-andesite.

118. 1,650 ft. E. of cor. to Sections 4, 5, 32, 33. Olivine-bearing pyroxene-andesite.

119. NW. cor. Red Lion Fraction, Section 7. Olivine-bearing pyroxene-andesite.

120. Capping of hill, 100 ft. E. of W. side center Anaconda, Section 22. Olivine-bearing pyroxene-andesite.

121. Willows No. 1, near W. side center, Section 27. Olivine-bearing pyroxene-andesite.

122, 123. Myers Peak, Section 12. Olivine-basalt.

124. From top of bluff, a little SE. of summit, on Lida road, Section 14. Olivine-basalt.

125. Alvarado, SE. cor., Section 13. Olivine-bearing pyroxene-andesite, near basalt.

126. Grubstake Fraction, on S. side of SW. cor., Section 4. Olivine-bearing pyroxene-andesite, near basalt.

127. Highwater, SW. cor., Section 19. Olivine-bearing pyroxene-andesite, near basalt.

128. From top of bluff, a little east of Lida road, after crossing summit, Section 14. Pyroxene-andesite.

129. Lower flow on malapais mesa, near divide on Lida road, S. of town, W. of road, SE. cor. of map. Felsite.

130. Normal piece from lower flow on mesa, SW. of town, Section 11. Felsite.

133, 134. Desert Rose No. 1, Section 24. Volcanic ash.

135. Tonopah Club, Section 24. Volcanic ash.

136. Locality unknown. Volcanic ash.

137. Near Tinhorn, Section 5. Volcanic tuff.

138. An indurated rock of doubtful identity.

139. West slope Columbia mountain, near foot, Section 35. Tuff.

140. Lucky Boy, inclusion in alaskite and rhyolite, Vindicator mountain, Section 36. Indurated shale.

141. SW. end of Columbia mountain, inclusion in alaskite and rhyolite, principally former, Section 35. Black slate or indurated shale.

142, 143. Locality unknown. Silicified rock, indurated porphyry.

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PHILADELPHIA, PA.
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TABLE OF CONTENTS.

SECTION I. INSTITUTE ANNOUNCEMENTS.

PAGE
List of Officers, ... iv
Bi-Monthly Bulletin, ... v
United Engineering Society Building, ... vi
Library, ... xi
Membership, ... xvii

SECTION II. TECHNICAL PAPERS.

No. 1. WILBUR E. SANDERS. A Reference Scheme for Mine-Workings, . 315
No. 2. N. LILIENBERG. Piping in Steel Ingots, ... 327
No. 3. JAMES E. YORK. Improvements in Rolling Iron and Steel, . . 337
No. 4. BIOGRAPHICAL NOTICES OF 1905, ... 359
No. 5. ALBERT R. LEDOUX, A Novel Method of Mining Kaolin, . . 379

PAGE
No. 6. C. A. MEISSNER. Notes on the Gayley Dry-Air Blast Process, . 382
No. 7. ERNEST A. HERSAM. Screens for Sizing, ... 423
No. 8. E. J. McCAUSTLAND. The Effect of Low Temperature on the Recovery of Steel from Overstrain. 447
No. 9. THOMAS T. READ. The Amalgamation of Gold Ores, . . . 467
No. 10. PROCEEDINGS OF THE BETHLEHEM MEETING, FEBRUARY, 1906, . 497

SECTION I.

INSTITUTE ANNOUNCEMENTS.

This section contains announcements of general interest to the members of the Institute but not always of sufficient permanent value to warrant republication in the volumes of the *Transactions*.

OFFICERS.

For the year ending February, 1907.

Council.*

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(Term expires February, 1907.)

Vice-Presidents of the Council.

WILLIAM P. BLAKE.......................Tucson, Ariz.
THOMAS F. COLE.......................Duluth, Minn.
IRVING A. STEARNS.......................Wilkes-Barre, Pa.

(Term expires February, 1907.)

HENRY M. HOWE.......................New York, N. Y.
J. B. GRANT.......................Denver, Colo.
JAMES D. HAGUE.......................New York, N. Y.

(Term expires February, 1909.)

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CHARLES H. SNOW.......................New York, N. Y.

(Term expires February, 1907.)

A. A. BLOW.......................Washington, D. C.
FRANK LYMAN.......................New York, N. Y.
T. A. RICKARD.......................San Francisco, Cal.

(Term expires February, 1908.)

THEODORE DWIGHT.......................New York, N. Y.
WALTER WOOD.......................Philadelphia, Pa.
WM. FLEET ROBERTSON.......................Victoria, B. C., Can.

(Term expires February, 1909.)

Secretary of the Council.

R. W. RAYMOND, No. 99 John Street.......................New York, N. Y.

(Term expires February, 1907.)

Assistant Secretary and Editor.

JOSEPH STRUTHERS.......................New York, N. Y.

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JAMES GAYLEY, President; JAMES DOUGLAS, Vice-President; R. W. RAYMOND, Secretary; FRANK LYMAN, Treasurer; JOSEPH STRUTHERS, Assistant Secretary and Assistant Treasurer.

Directors.

JAMES GAYLEY, FRANK KLEPETKO, FRANK LYMAN.

(Term expires February, 1907.)

JAMES DOUGLAS., JAMES F. KEMP, ALBERT R. LEDOUX.

(Term expires February, 1908.)

THEODORE DWIGHT, CHARLES H. SNOW, R. W. RAYMOND.

(Term expires February, 1909.)

Consulting Attorneys, Blair & Rudd, New York, N. Y.

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* Secretary's Note.—The Council is the professional body, having charge of the election of members, the holding of meetings (except business meetings), and the publication of papers, proceedings, etc. The Board of Directors is the body legally responsible for the business management of the Corporation, and is therefore, for convenience, composed of members residing in New York.

BI-MONTHLY BULLETIN.

For the convenience of persons who desire to file, or otherwise use separately, the technical papers in Section II. of the Bulletin, each of these papers has been paged and wired by itself; the whole collection being held together by a single, heavy wire, upon the removal of which it will fall apart into individual pamphlets, substantially like those formerly issued.

A small stock of separate pamphlets, duplicating the technical papers given in Section II. of this Bulletin, is reserved for those who desire extra copies of any single paper.

All communications concerning the contents of this Bulletin should be addressed to Dr. Joseph Struthers, Assistant Secretary and Editor, 99 John St., New York City (P. O. Box 223; Telephone number 5477 John).

UNITED ENGINEERING SOCIETY BUILDING.

Although the noble building provided in New York City by Mr. Carnegie for the United Engineering Society has been pushed to about half-completion, the ceremony of laying its corner-stone was not performed until Tuesday afternoon, May 8, 1906. The stone lies just back of the southeast corner of the building, on the north side of West 39th Street.

Among those present were Mr. and Mrs. Carnegie, Miss Whitfield, the sister of Mrs. Carnegie, Ralph W. Pope, Secretary of the Institute of Electrical Engineers, Frederick R. Hutton, Secretary of the Society of Mechanical Engineers, Rossiter W. Raymond, Secretary of the Institute of Mining Engineers, Charles H. Haswell, the first Chief Engineer of the United States Navy (1836–1851), now in his ninety-seventh year, John Fritz, of the Bethlehem Steel Company, William H. Fletcher, President of the Engineers' Club, E. E. Olcott, President of United Engineering Society, and other interested friends.

After an inspection of the interior of the building, the group formed about the corner-stone, which had been draped with the American flag. The exercises were opened by Mr. Olcott, who appropriately welcomed Mr. Carnegie, and briefly expressed the essential value of the building, saying, in part:

> "The societies to be housed underneath this roof have as their aim the preserving and putting in tangible form of the records of scientific accomplishments so as to avoid the repetition of mistakes. The possibility of finding the records of these results all at one center, so near the great Public Library of our city, will be an inestimable advantage to all professions. It is an occasion of no ordinary moment, therefore, when we can welcome Mr. Carnegie and have him lay for us the corner-stone of this great building which his liberality has provided."

Mr. Carnegie responded in happy vein, thanking the committee for their greeting, and expressing his pleasure in being able to do what he had done to further so worthy a cause. Among other things, he said:

> Go over to the capitals of Europe, and you will find in little buildings the electrical engineers here, the mechanical engineers there and the mining engineers yonder, about a mile or more apart; and yet they think that they can keep pace with our engineers in a country where they meet and consult together. The principle of union in science is of as vital importance as in political affairs.

A moment ago there came to my mind a little quotation from Kipling. It was about a Scotch engineer. I can usually quote from memory, but I cannot just now. Anyway, it described a very pious Presbyterian Scotch engineer sitting before his engine, admiring it. He gave all the credit for the engine to God.

But there followed seven days' battling in the ice and three days in the currents of the ocean. Then said the engineer:

"O Lord, Ye ken Ye need an engineer!"

So He did. And the world would be a pretty poor place without them. Now, I hope they will complete and get into the building, and soon invite us to the first banquet.

Mr. T. C. Martin, Secretary of the Committee of Arrangements, now presented to Mrs. Carnegie a silver trowel, thus inscribed:

TROWEL
used by
MRS. ANDREW CARNEGIE
in laying the
CORNER-STONE
of the
ENGINEERING SOCIETIES
BUILDING
May 8, 1906.

Mrs. Carnegie advanced to the corner-stone and deposited in the lead box for enclosure within the stone a little case, containing a proof set of United States coins of 1906,—gold pieces of $20, $10, $5, $2.50; silver pieces of 50c., 25c., 10c., 5c.; and a 1 cent piece; also a gold plate prepared by the Society of Mechanical Engineers, on which was engraved the presentation letter from Mr. Carnegie, as follows:

NEW YORK, February 14, 1906.

Gentlemen, American Society Civil Engineers, American Society Mechanical Engineers, American Institute Mining Engineers, American Institute Electrical Engineers, and the Engineers' Club.

IT WILL GIVE ME GREAT PLEASURE TO GIVE, SAY, ONE MILLION DOLLARS* TO ERECT A SUITABLE UNION BUILDING FOR YOU ALL, AS THE SAME MAY BE NEEDED.

WITH BEST WISHES, TRULY YOURS,
ANDREW CARNEGIE.

---

* Subsequently increased to $1,500,000, which includes, besides the building for the Societies, the house of the Engineers' Club.

The lead box, the further contents of which are listed below, was now sealed and placed within the stone; then Mrs. Carnegie applied with the trowel a little cement and tapped the stone with an ivory mallet, thus completing the ceremony.

The box contained, besides the mementoes put in by Mrs. Carnegie, the following articles:

From United Engineering Society:
 Charter and By-Laws.
 Circular on Engineering Building.
 Report of Committee on Plans.
 Progress of competition for selection of architects.
 Plans of Engineering Building, 1905.

From the American Society Mechanical Engineers:
 Year-Book Society Mechanical Engineers.
 Letter-heads, with impress of seals.
 Gold plate with Carnegie letter, as above.

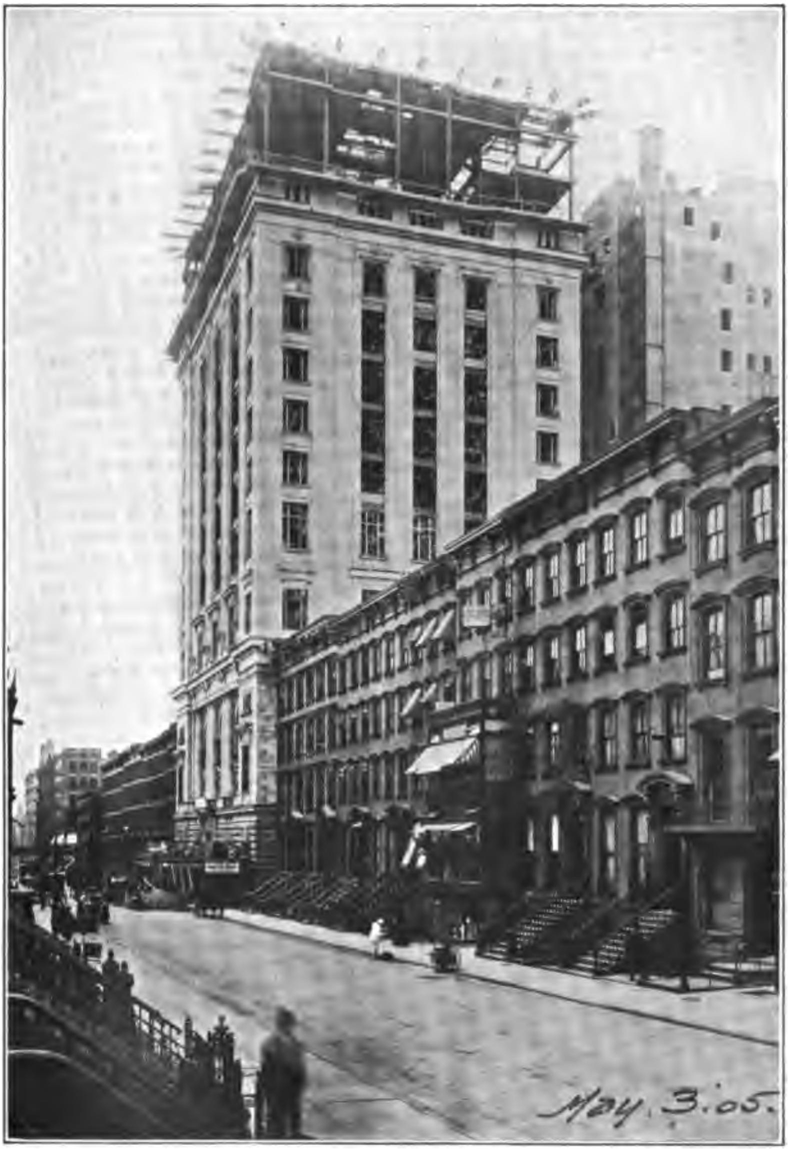
From the American Institute of Mining Engineers:
 List of Members, 1905, including Constitution, etc.
 Certificate of the Honorary Membership of Andrew Carnegie.
 Memorial Volume of A. L. Holley.
 Biographical Notice of Eckley B. Coxe.
 Biographical Notice of R. P. Rothwell.
 Biographical Notice of Abram S. Hewitt.
 Biographical Notice of T. Sterry Hunt.
 Biographical Notice of T. M. Drown.
 Biographical Notice of Thomas Egleston.
 Biographical Notice of J. P. Lesley.
 Biographical Notice of Joseph Le Conte.
 Copies of Vols. I. and XXXV. of *Transactions.*
 Portrait of present Secretary.

From the American Institute of Electrical Engineers:
 Proceedings of Electrical Engineers, bound Volume XXIV.
 List of Members.
 Announcement of Meetings.
 Mailing List.

From the Engineers' Club:
 Annual Report, 1904.
 Pamphlet describing Engineers' Club New Building.

Scientific American of May 5, 1906.
Harper's Weekly of April 21, 1906.
New York *Morning Sun, Press, Times, Tribune, Herald* of May 8, 1906.
New York *Evening Sun, Evening Post, Evening Mail* of May 8, 1906.

Messrs. Hale & Rogers, the architects, furnish the following condensed statement of the present condition of the building :—



View of the United Engineering Society Building, Nos. 25 to 33 West 39th St., New York City, Taken May 3, 1906.

"Since the last photograph was published in the March *Bulletin*, the work on the Engineering Building has gone ahead steadily and rapidly. The steel structural work at the present time is practically finished. The terra-cotta floors and roof have been put in place, and the exterior brick and terra-cotta work has reached the library floor.

"In the photograph on the foregoing page, one notices at the very top of the building a series of projecting frame-work. These projections are not the frame for the cornice, but are a part of the paraphernalia used with the modern exterior scaffolding, which is raised and lowered at will.

"The body of the structure is buff brick, which harmonizes well with the limestone below and the terra-cotta trimmings. The window-framing, which is being put in place, is of metal, as required by law.

"The corner-stone for the building, laid on May 8, 1906, cannot be seen in the photograph, but it is just next to the brownstone house on the right-hand side of the building, behind the outdoor stair-rail.

"In the next four months building should go ahead very rapidly. When everything is satisfactorily closed in, about June 1, the work of plastering will be begun, and the drying out will be in good summer weather.

"The architects have practically finished the interior detail drawings, and the sub-contractors are already preparing their materials for the marble-work, wood-work, etc., that will go in within the next few months."

Thus, the main construction of the new building is nearly completed, and it is hoped that occupation may be possible by January 1, 1907. The cost of the building will be about $1,050,000; the remainder of the additional half-million given by Mr. Carnegie going to the new building of the Engineers' Club, now erecting on West 40th Street, adjoining the Engineering Society Building on West 39th Street. The ground purchased by United Engineering Society for the general building has cost $502,000, which sum is represented by 4 per cent. bonds, the principal of which has been advanced by Mr. Carnegie in addition to his generous gift of the building, and which are to be paid by the three societies in annual instalments, covering 20 years.

LIBRARY.

Accessions.

From February 16 to May 8, 1906.

American Association for the Advancement of Science.

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE. *Proceedings.* Vol. 54. 8vo. Washington, 1905.

American Electrochemical Society.

AMERICAN ELECTROCHEMICAL SOCIETY. *Transactions.* Vol. 8. 8vo. Philadelphia, 1906.

Mrs. H. M. Boies.

MILLS, L. F. and OTHERS. *Henry Martin Boies.* Appreciation of his Life and Character. xiii, 297 p. pl. por. 8vo. New York, 1904.

Bureau of Geology and Mines of Missouri.

MISSOURI BUREAU OF GEOLOGY AND MINES. *Report.* Vol. iv, 2d Series. 8vo. Jefferson City, 1905.

Canadian Society of Civil Engineers, Montreal.

DAWSON, W. B. *Tide Levels and Datum Planes on the Pacific Coast of Canada.* 22 p. 8vo.

FELLOWES, C. L. *Toronto's Experience with Conduits.* 7 p. 8vo.

GOLDMARK, HENRY. *Formulas for Reinforced Concrete Beams.* 25 p. 8vo.

Civil Engineers Club of Cleveland, Ohio.

CIVIL ENGINEERS CLUB OF CLEVELAND. *Annual Register and Constitution,* April 1, 1906. 49, xxiv. p. 12mo. Cleveland, 1906.

Department of Mines of Nova Scotia.

NOVA SCOTIA—DEPARTMENT OF MINES. *Report,* 1905. 8vo. Halifax, 1906.

Department of Mines of Pennsylvania.

PENNSYLVANIA—DEPARTMENT OF MINES. *Report* (Bituminous), pt. 2. 8vo. Harrisburg, 1906.

A. Faber du Faur.

KARSTEN, C. J. B. *Handbuch der Eisenhüttenkunde.* Vol. 5. 8vo. Berlin, 1841.

Geological Survey of Victoria.

VICTORIA GEOLOGICAL SURVEY. *Bulletin.* Nos. 1–11, 13–17. 8vo. Melbourne, 1903–'05.

Contents: **No. 1.** The Geology of the Berry Lead at Spring Hill and Central Leads, by J. W. Gregory. **No. 2.** The Pyrenees Gold-Fields, by W. Bradford. **No. 3**. The Rocky Lead District, Daylesford, by W. Bradford. **No. 4.** The Enfield Gold-Field, by W. Bradford. **No. 5.** The Dunolly Gold-Field, by W. Bradford. **No. 6.** The Clunes Gold-Field, by W. Bradford. **No. 7.** The Stawell Gold-Field, by W. Bradford. **No. 8.** Instructions for the Use of the Aneroid Barometer, by J. W. Gregory. **No. 9.** The Dunolly-Wedderburn Gold-Fields, by W. Bradford. **No. 10.** The Egerton-Gordon Gold-Field, by W. Bradford. **No. 11.** The Harrietville Gold-Field, by W. Bradford. **No. 13.** The Berringa Gold-Field, by W. Bradford. **No. 14.** The Malden Gold-Field, by W. Bradford. **No. 15.** The Nerrena or Little Bendigo Gold-Field, by W. Bradford. **No 16.** The Monazite Deposit at Pinch Swamp Creek, Bonang District, County of Croajingolong, by M. Copland. **No. 17.** The Newbridge Gold-Field, by S. B. Hunter, with an Appendix on the Matrix or McEnvoy's Reef, Rheola, by E. J. Dunn.

——— *Memoirs.* Nos. 1–3. f°. Melbourne, 1903 '05.

Contents: **No. 1.** The Chiltern Gold-Field, by S. B. Hunter. **No. 2.** The Castlemaine Gold-Field, by W. Baragwanath, Jun. **No. 3.** The Wood's Point Gold-Field, by O. A. L. Whitelaw, with Appendix on the Propylitic Diorites and Associated Rocks of the Wood's Point Gold-field, by J. W. Gregory.

——— *Records.* Vol. 1. Pts. 1–3. 8vo. Melbourne, 1902–'04.

H. P. Gillette.

GILLETTE, H. P. *Handbook of Cost Data for Contractors and Engineers.* xii, 610 p. il. 12mo. New York, 1906. ($4.00 net, *postpaid*).

[SECRETARY'S NOTE.—The author of this book is already well-known to engineers and contractors through his monographs on "Rock-Excavation, Methods and Cost," "Earth Work and its Cost," and "Economics of Road Construction." The present manual, a 610-page volume of pocket-size, contains summaries, formulas, examples and suggestions concerning methods of cost-keeping, the preparation of estimates and the cost of various operations, including excavation of earth and of rock; quarrying; crushing; the working of roads, pavements and walks, stone-masonry; structures in concrete; water-works, sewers, conduits and drains; piling, trestling and timber-work; the erection of buildings; steam and electric railways; the erection and painting of bridges; railway and topographic surveys, and numerous other operations. A survey of its comprehensive and carefully arranged contents inspires the belief that it must be extremely valuable to people of two classes: those who are already and those who are not, but desire to become acquainted with the practical problems of which it treats.—R. W. R].

Charles Griffin and Company.

ROSE, T. K. *Metallurgy of Gold.* Ed. 5. xiii., 534 p. il. pl. 8vo. London, 1906.

[SECRETARY'S NOTE.—This is one of the admirable series of Metallurgical text-books, prepared under the general editorial supervision of the late Prof. Roberts-Austin. The first edition appeared in 1894; a second was immediately called for; and a third and fourth followed at brief intervals. In this fifth edition, the name of Roberts-Austin no longer appears upon the title page; but the reputation of Dr. Rose, who prepared under his direction the first edition furnishes ample guaranty of the authority and value of the treatise. Dr. Rose has omitted from this edition some material which had lost value through the lapse of time, and added much information of more recent date needed to bring up to date the record of progress in the treatment of gold-bearing ores. The new matter includes an entire chapter on the re-grinding of gold-bearing material for a second treatment—a subject which has commanded of late much attention.—R. W. R.]

Hoofdbureau von het Mijnwezen in Nederlandsch Öest-Indie.

Jaarboek van het Mijnwezen in Nederlandsch Öest-Indie. Year 34, 1905. 8vo. Batavia, 1905.

P. G. Holms.

HOLMS, P. G. *Directory of Agencies, Mines and Haciendas,* 1905–1906. 8vo. Mexico, 1905. (Price, $10.00.)

[SECRETARY'S NOTE.—This directory, compiled with the cordial approval of President Diaz and the Ministers of the Department of the Republic of Mexico most directly concerned in such a work, as well as the assistance of the Governors of the several States of Mexico, the managers of Mexican mines and the commercial agents in the Republic of domestic and foreign houses will be highly valuable, not to say indispensable, to all who need such a comprehensive and accurate guide to the industries of Mexico and their representatives. For the convenience of American readers, all important terms are given in English, as well as in Spanish. In fact, the English language largely predominates in its pages. The book contains, in 372 pages of ordinary octavo size, an immense number of addresses, duly classified, and accompanied with much pertinent and useful information. The table of mines, for instance, gives the name and address of the company or individual owner; the name of the mine and of the resident manager; the metal or metals produced; the kind of power employed; the number and nature of mills, etc.; the capacity of the mills; cyanide plants or smelting furnaces; and the number of men employed. A new enlarged and improved edition is said to be already in press.—R. W. R.]

Illinois Central Railroad Company.

ILLINOIS CENTRAL RAILROAD COMPANY. *Annual Report,* 54th. f°. Chicago, 1904.

Institution of Mining and Metallurgy.

INSTITUTION OF MINING AND METALLURGY. *Bulletin* Nos. 18, 19. 8vo.

BANNISTER, C. O. *On the Assay of Auriferous Tin-Stone.* 7 p. 8vo.

COLLINS, E. A. *Notes on a Prospecting Shaft in the Goldfield District, Goldfield, Nevada.* 3 p. 8vo.

Institution of Mining and Metallurgy.

COLLINS, E. A. *On the Use of the Impact Screen in Tin Dressing.* 2 p. 8vo.

HILL, L. H. *The Hydraulic Filling of a Coal Seam at Lens, Pas de Calais, France.* 12 p. il. 8vo.

MACDONALD, W. F. *The Mitchell's Creek Gold Mines, New South Wales.* 14 p. il. 8vo. London, 1906.

MARKS, F. S. and MARKS, G. N. *The Bucket Dredging Industry.* 43 p. il. 8vo.

MORRIS, C. J. *The Production of High Grade Gold Bullion from Zinc-Box Precipitates.* 5 p. 8vo.

PETTIT, A. E. *Sinking, Development and Underground Equipment of Deep Level Shafts on the Rand.* 34 p. il. 8vo.

SLEEMAN, H. R. *The Detailed Mapping of Stoping Areas.* 7 p. il. 8vo.

NOTE.—The above pamphlets are published separately by the Institution of Mining and Metallurgy. For information regarding them, address the Secretary, C. McDermid, London, Eng.

Interstate Commerce Commission.

U. S.—INTERSTATE COMMERCE COMMISSION. *Annual Report*, 19th. 8vo. Washington, 1905.

Iron Silver Mining Company.

IRON SILVER MINING COMPANY. *Report*, 1905. 8vo. New York–Detroit, 1905.

Kaiserliche Patentamt.

GERMANY-KAISERLICHE PATENTAMT. *Nachtrag der Katalog.* No. 5. 8vo. Berlin, 1905.

Königliche Preussische Geologische Landesanstalt und Bergakademie zu Berlin.

Jahrbuch. Year 23. 8vo. Berlin, 1905.

Koninklijk Instituut van Ingenieurs.

KONINKLIJK INSTITUUT VAN INGENIEURS. *Catalogue der Boekerij van Koninklijk Instituut van Ingenieurs.* Tweede Supplement vii, 186 p. 8vo. s'Gravenhage, 1905.

Lake Superior Mining Institute.

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ROBINE, R. and LENGLEN, M. *The Cyanide Industry.* xi, 480 p. il. 8vo. New York, 1906. (Price, $4.00.)

[SECRETARY'S NOTE.—This translation, by one of the distinguished chemists of the U. S. Department of Agriculture, renders accessible to American chemists the treatise prepared by two eminent Parisian chemical engineers, and published in France, in the *Encyclopédie Industrielle.* Its usefulness has been enhanced by an index from the hand of the translator, and an appendix containing a digest of U. S. patents relating to cyanide processes for the recovery of precious metals, reprinted from the monograph of Dr. Charles E. Munroe, of the U. S. Department of Commerce and Labor.

Dr. Leclerc, the accomplished translator, is less interested in the metallurgical than in the agricultural application of the subject, and hopes that one of the results of this work may be "the successful fixation of atmospheric oxygen on an industrial scale."—R. W. R.]

J. H. C. Williams.

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S. S. Wyer.

WYER, S. S. *Producer-Gas and Gas-Producers.* 296 p. 8vo. New York, 1906. (Price, $4.00.)

[SECRETARY'S NOTE.—This treatise deserves special attention and praise, not only because it deals with a modern subject of universal importance, the literature of which must be sought in numerous scattered contributions to technical societies and journals, but also because it summarizes and discusses that literature with comprehensive fullness and critical discrimination; furnishing a bibliography, with the aid of which each student can pursue further inquiries for himself. Limited portions of the book have been published as papers in the *Transactions* of the American Institute of Mining Engineers; and the whole of it would be equally worthy and welcome for such publication if there were room for it.—R. W. R.]

PURCHASES.

FISCHER, F. *Jahres-Bericht uber die Leistungen der Chemischen Technologie.* Vol. 51, new ser. 36. 8vo. Leipzig, 1906.

MEMBERSHIP.

The following list comprises the names of those persons elected as Members or Associates, who duly accepted election during March and April, 1906:—

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NECROLOGY.

The following list comprises the names of members whose deaths have been reported to the Secretary of the Institute during March and April, 1906. It is doubtless incomplete, by reason of delay in sending such reports. Members are requested to read it carefully, and to call the attention of the Secretary to any omissions which they may discover.

Date of Election.	Name.	Date of Decease.
1905.	*R. Scott Allen, Philadelphia, Pa.,	February, 1906.
1900.	*George H. Arlett, Chihuahua, Mexico,	March 19, 1906.
1896.	*E. E. Breisch, Moundsville, W. Va.,	February 14, 1906.
1895,	*Horace F. Brown, San Francisco, Cal.,	April 15, 1906.
1904.	**John H. Fraser, Guayaquil, Ecuador, So. Amer.,	April 1, 1906.
1889.	*Francis L. Sperry, Tallmadge, Ohio,	April 17, 1906.
1877.	**Edward G. Stoiber, Paris, France,	April 21, 1906.

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* Member. ** Life Member.

SECTION II.

TECHNICAL PAPERS AND DISCUSSIONS.

[The American Institute of Mining Engineers does not assume responsibility for any statement of fact or opinion advanced in its papers or discussions.]

A detailed list of the papers contained in this section is given in the Table of Contents, pages i and ii.

Comments or criticisms upon all papers given in this section, whether private corrections of typographical or other errors or communications for publication as "Discussions," or independent papers on the same or a related subject, are earnestly invited.

ERRATUM.

Correction to *Bi-Monthly Bulletin*, No. 8, March, 1906.

Page.	Line.	
1	22	for " 161 " read " 139."

SUBJECT TO REVISION.

[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

A Reference-Scheme for Mine-Workings.

BY WILBUR E. SANDERS, E. M., HELENA, MONT.

(Bethlehem Meeting, February, 1906.)

AT some period during the operation of metalliferous and other commercially valuable mineral-deposits in connection with their underground mining, when the developments therein have become so extensive that their description is tedious and confusing, some scheme for naming or numbering the various workings and their parts is necessary for convenience of reference. A simple and symmetrical yet expansive system of classification must be devised, one that is capable of being extended to cover all possible exigencies and conditions of future operations within the property.

Such a scheme, properly arranged, greatly simplifies communication between the various departments of the mining business, as, for instance, between the administrative and the operating departments of the concern, and is of the greatest assistance to the officers of the mine in enabling them to locate and describe particular points and parts of workings and specific kinds of work. Again, in the proper segregation and differentiation of mine-accounts, when they are carried out with that detail which will furnish ready information concerning the cost of a particular piece of work, or the various items and totals of expense connected with the development, operation and repair of each or all of the mine-workings, some such method of designation becomes a necessity. Moreover, such a plan is admirably adapted to the needs of the mining engineer, who, in connection with his reports upon mining-properties, is sometimes required, in his descriptions of certain blocks of ore, to locate lists of assays of samples taken from many and various places, and to designate workings and parts of workings that are located in different parts of the mine, sometimes at points wide apart.

To write out in full a sufficient description of any particular

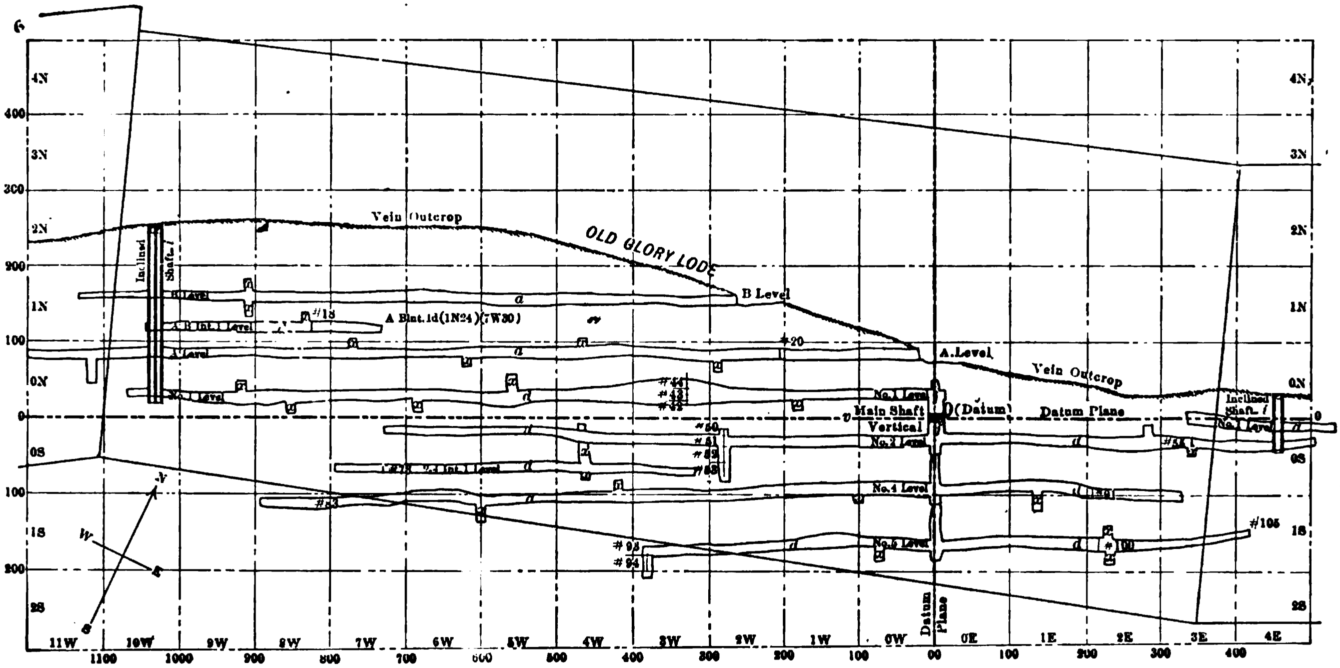


FIG. 1.—OLD GLORY QUARTZ-LODE MINING CLAIM, PLAN.

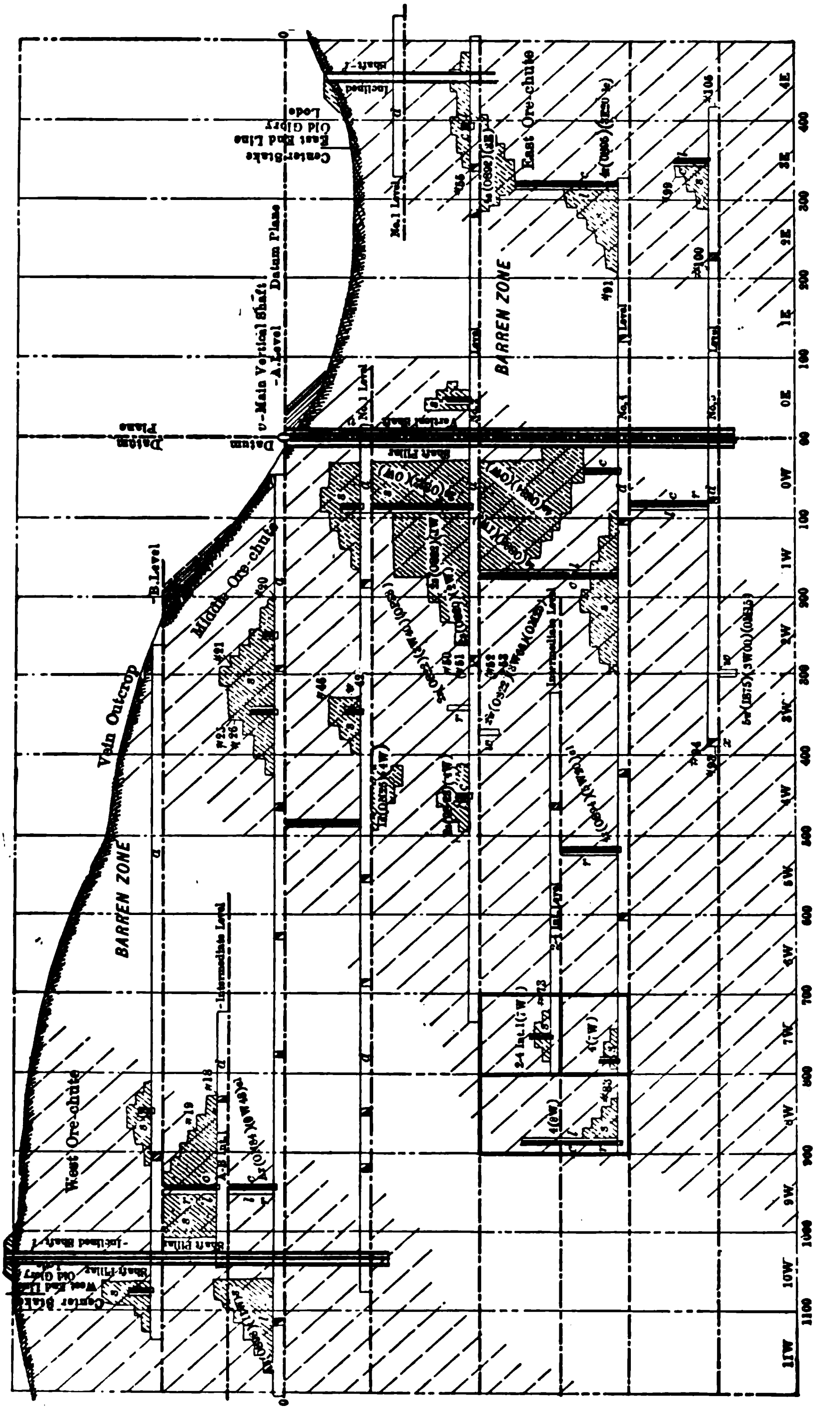


FIG. 2.—OLD GLORY QUARTZ-LODE MINING CLAIM. LONGITUDINAL SECTION.

locality or working of a mine, or even to explain the locations from which a lot of samples have been taken, would be far too cumbersome for practical purposes, and such a description would lack the essentials of systematic classification. For cases in which many and extensive developments are involved, the scheme may be founded upon some progressive system that will designate points and parts of workings and, by inference, the operations that are being carried on therein; and these results being obtained, they should be capable of concise expression, stenographically, by symbols. The plan must be such in principle that it may be made to apply to all classes of underground mining, and be capable of fulfilling all the requirements that future extension of the mine-workings shall demand of it.

For the purpose of illustration, assume that the Old Glory quartz-lode mining-claim (Fig. 1, plan; and Fig. 2, longitudinal section), contains a single fissure-vein that outcrops upwards along the face of a hill, and which is developed within the vein along its strike, by the adits, *a*, of A and B tunnel-levels, and the interior drifts, *d*, of Nos. 1, 2, 4 and 5 levels, together with intermediate drifts and workings; the dip of the vein being at a steep angle towards the south. Furthermore, the mine is developed in depth by a main vertical working-shaft, *v*, and two subsidiary inclined shafts, *i*, the latter sunk on the vein. The levels of the mine comprise the adits, *a*, the storage-junctions or stations, *j*, at the junctions of horizontal workings with the principal inclined and vertical shafts, the cross-cuts, *x*, run from the stations of the vertical shafts to intersect the vein at the level of the different stations, the drifts, *d*, run from such cross-cuts horizontally along or near the vein, together with other connected and related interior workings.

Within the vein, for purposes of exploitation, ventilation and communication, and for the extraction of ores, other workings have been constructed; raises, *r*, have been carried upward from the several drifts and adits into blocks of ground overhead that contains the ore-deposits of the levels (when such bodies are attacked by overhand stoping), or into and through barren ground for purposes of ventilation; winzes, *w*, have been sunk below the drifts into blocks of ground that contain the ores belonging to the level from which the winze is sunk when the deposit is attacked by underhand stoping, or that belong to the level beneath whenever they are extracted from that level; stopes, *s*, have been opened up for the purpose of winning the valuable materials from their places of deposit; and chutes, *c*, have been built up in order to bring the broken ores from the stopes to the drifts, that they may be drawn into vehicles and carried thence to surface, while cross-cuts, *x*, have been driven from the various drifts into the country-rock to either side of the vein for the purpose of prospecting its hanging-wall and foot-wall for ore-bodies, or evidence of valuable minerals. These are the workings that are of general utility in carrying out the processes of development and operation of a mining property.

Since the mine-maps, drawn to a desirable scale, are a sufficiently exact reproduction of the workings of a mine, it follows that a plan for naming and numbering such workings for reference will begin with and be developed from the maps, and, for the sake of reference, such a scheme must be exhibited upon them. For the sake of brevity in description, certain symbols, letters or figures, are employed to designate the various mine workings, as follows:—

PASSAGEWAYS.

Horizontals:

- *a.* Main and subsidiary exterior horizontal passageways, as adits and tunnels.
- *d.* Main and subsidiary interior horizontal longitudinal passageways, as drifts, driveways, gangways, etc.
- *j.* Storage-junctions, stations or platts.
- *x.* Main and subsidiary interior horizontal transverse passageways, as cross-cuts, cross-headings, etc.

Inclines:

- *i.* Main and subsidiary inclined shafts.

Verticals:

- *v.* Main and subsidiary vertical shafts.

Ways:

- *c.* Chutes, rock-ways, mill-holes, etc.
- *l.* Ladder-ways, man-ways, etc.
- *r.* Raises.
- *w.* Winzes.

EXTRACTION PLACES.

s. Stopes, stalls, rooms, chambers, etc.
b. Backs, breasts, bottoms or sides, *in ore.*
p. Pillars of all kinds.

It is not probable that the course or strike of a vein will lie exactly in a N–S. or in an E-W. direction, but in a general way its strike and dip must be taken into account, and made use of for the purpose of locating the relative positions of the mine-workings, or any part or parcel thereof, with reference to some initial point of the mine, at which, properly, our scheme may be made to begin. The vein, therefore, lies horizontally in an easterly and westerly or northerly and southerly direction, and any particular working or part of a working is located and arbitrarily described as being east or west and north or south of our assumed initial point of beginning, the datum-point or 0 of the scheme. Direction with reference to this 0 point is symbolized by the initial letter of the bearing in capital form, thus: N. = North or northerly; S. = South or southerly; E. = East or easterly, and W. = West or westerly.

Similarly, as regards the elevations of mine-workings, or of parts or parcels thereof, being their vertical measurements above or below an assumed or accepted initial point, such distances with regard to that point are symbolized thus: P = (plus) above; M. = (minus) below.

Any and all points of mine-workings are referred, for purposes of location, to a system of base or datum-planes "00" which are passed through the datum or "0" point of the scheme in three directions that are at right-angles to each other, as follows: a vertical transverse datum-plane, 00, passing through 0-point transversely across or at right angles to the course or strike of the vein; a vertical longitudinal datum-plane, 00, passing through 0-point parallel to the strike of the vein; a horizontal datum-plane, 00, passed through 0-point at right angles, or approximately at right angles, to the vertical datum-planes of the system. By means of these three planes any point whatsoever, be it north, south, east or west and above or below 0 of the scheme, may be referred to that dutum (0) by means of co-ordinate measurements.

For purposes of measurement and description, three series of planes that are parallel to the above datum-planes are passed through, in connection with the workings of the mine. Those planes, which are passed parallel to the vertical transverse and vertical longitudiual datum-planes, are established at intervals of 100 ft., while those which are passed parallel with the horizontal datum-plane are made to coincide with the planes of the floors of the different levels of the mine, whatever may be the vertical interval between the workings. By means of the datum-planes explained above, and the three series of parallel planes related to them and connected therewith, the rock-masses, surrounding and enclosing the workings of the mine, are divided and separated into cubical blocks, any point or part of which may be located with reference to the enclosing planes, or to 0 by means of longitudinal, transverse and vertical co-ordinates.

The series of vertical transverse planes, running north and south, are numbered in hundreds of feet, the distances between the different planes and the datum-plane being thus symbolized, as being 100, 200 *et seq.* to the east and to the west of datum-plane. Similarly, the series of vertical longitudinal planes running east and west are numbered in hundreds of feet to represent the distances north and south from the datum-plane of the different planes of the series, thus 100, 200 *et seq.* Since these planes are numbered in hundreds of feet, those blocks of ground immediately adjoining datum or 0-point of the system would be 0 hundred east, or west, or north, or south; for the reason that any point in such blocks would be 0 hundred east or in other directions plus the distance of that point from the 0-point; as a point 25 ft. north of 0 would be 025, preferably to be written 0N25, or similarly 0E25 if 25 ft. eastward from 0. Zero- or datum-block being thus established in each direction with reference to the scheme and to the 0-point, other blocks follow in sequence, as 1N, 2N, etc., 1E, 2E, etc., 1S, 2S, etc., and 1W, 2W, etc. By way of illustration, points 25 ft. from the beginning of certain blocks would read thus: 1N25 in block 1N; 4E25 in block 4E; 7S25 in block 7S; 12W25 in block 12W, the last of the above readings signifying that the assumed point is 1,200 plus 25 ft. west of 0 by the scheme. By thus describing and writing the location of a point, its direction or bearing, north, south, east or west, or above or below datum or 0, is so placed that it will separate the name or number of the block in which the point is established, from the distance of that point within the block from the beginning thereof, as signified by the final numerals written as tens, thus 25, or 05, etc.

The series of horizontal planes which are made to coincide with the floor-planes of the different levels are symbolized by the designation of the levels themselves. The horizontal datum-plane is made to coincide with the floor of the main working-tunnel, or with the collar of the main working-shaft of the mine, whether the same is a vertical or inclined shaft, this being doubly the fact when, as in the Old Glory lode assumed, the top of that shaft coincides with the floor-plane of the main-working, A tunnel. Adit-tunnel levels, employed for the development of the mine above the horizontal datum-plane, are designated by the first letters of the alphabet in capital form, as A, B, etc., the floor-plane of "A" level being made to coincide with the datum-plane. The interior levels employed for the development and operation of the mine from the horizontal datum-plane downward to the deep are designated by the numerals 1, 2, 3 *et seq.* in descending order. Abnormal intervals between levels would call for an omission from the sequence in order that intermediate levels to be constructed in the future may properly be designated in the scheme.

Points within the blocks belonging to the various levels are referred to the planes of those levels, such points being usually above, though they may be below, the floor-planes thereof. For illustration, assume that the various points are established 25 ft. above (0P25) the floors of certain levels, within the stopes belonging thereto, which, under the scheme, would be designated as within the stopes of, and above, No. 1 level, 1s(0P25); as within the stopes of and above No. 5 level, 5s(0P25); as within the stopes of and above B tunnel-level, Bs(0P25). Similarly, a point assumed to be 122 ft. above (1P22) the floor of a level, as within the stopes of "B" tunnel-level, would be designated Bs(1P22). Likewise, a point assumed to be 33 ft. below (0M33) the floor of a level, as No. 1 level, would be designated 1s(0M33).

In designating points for reference under the scheme the first symbol to be employed should be that of the level to which a point properly belongs, as A, B, etc., 1, 2, 3 *et seq.*

Following the symbol of the level comes the designation of the working within which the point is established, as *a*, *d*, *j*, *x*, *i*, *v*, *c*, *l*, *r*, *w*, *s*, etc., from the legend. And succeeding the above should be written the symbols of location by which the point is located in space with reference to the datum-planes of the system, and thereby to datum or 0-point. These symbols of location should invariably be written in order, the one fixing the location of the point in a north and south direction from 0-point being first noted, the one fixing the location of the point in an east and west direction from 0-point being next noted, while the one fixing the location of the point above or below the plane of the level to which it belongs should be noted last, each symbol of location being enclosed in brackets. In illustration, a point established 105 ft. north of the longitudinal datum-plane, 1,111 ft. east of the transverse datum-plane, and within the stopes 89 ft. above the floor-plane of A tunnel-level, would read, As(1N05) (11E11) (0P89). Similarly, a point 1,221 ft. south of the longitudinal datum-plane, 207 ft. west of the transverse datum-plane and within the stopes 25 ft. above the plane of No. 3 level, would be designated, 3s(12S21) (2W07) (0P25). If, instead of being in the stopes above or below the plane of the levels, the two points here assumed were within the adits and drift thereof, and therefore practically at the floor-planes of the levels, the latter designation might be discarded and the descriptions would then read: Aa(1N05) (11E11), and 3d(12S21) (2W07).

Fig. 3 exhibits in plan two horizontal or drift-workings, as driven within the vein along the floor-planes of Nos. 1 and 2 levels, and shows the stations, bearings and distances established by the mine-surveys, together with the method by which the points of intersection of the various planes of the system with the workings may be located and fixed therein. In this exhibit, datum is located at the collar of the vertical main working-shaft, through which point are passed the vertical transverse, the vertical longitudinal, and the horizontal datum-planes at right angles to each other, for purposes of establishing and describing the locations of points and parts of workings of the mine.

In Fig. 3 it may be noted that the drift of level No. 1 bends towards the north to such a degree that the plane, 100 ft. east of the transverse datum-plane, instead of intersecting the working at a point along its course that is just 100 ft. from the datum-plane or survey-station No. 1, intersects it rather at a point that is by survey-courses 50 + 40 + 23 = 113 ft. east of survey-station No. 1. Therefore, in fixing this intersection at its proper *locus* within the working, we would measure eastward from survey-station 1E, No. 2, a distance of 23 ft., and the point thus established would mark the beginning of block 1E, and should be so designated both within the working and upon the map. Similarly, from the survey-courses, the point of intersection of the 200-ft. plane, the commencement of block 2E of the system, with No. 1 level, drift is 217 ft. east of survey-station No. 1, and 104 ft. east of the intersection of the 100-ft. plane with the drift. This point may be established and marked within the drift by measuring eastward a distance of 43 ft. from survey-station 1E, No. 4. The various points at which the divisional planes of the system intersect the mine-workings being established from the mine-surveys, and permanently marked within those workings, it then becomes easily possible to locate and describe any point within any particular block of ground at which any material exists or any particular piece of work is being carried on, both upon the map and within the mine.

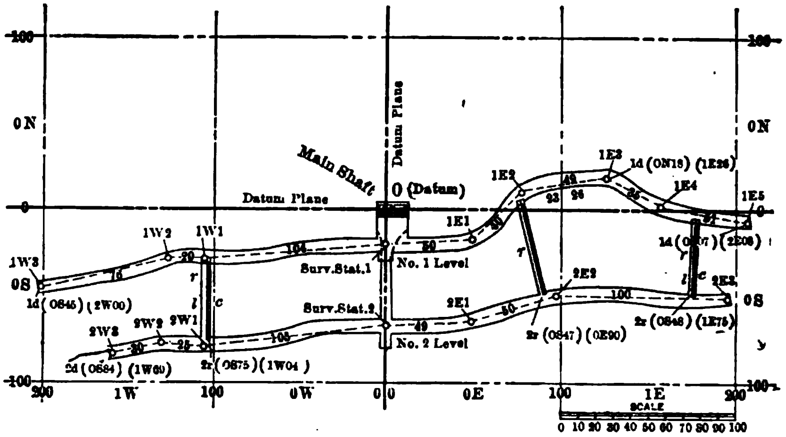


FIG. 3.—OLD GLORY QUARTZ-LODE MINING CLAIM. PLAN OF TWO DRIFT WORKINGS.

The location of raises, man-ways, chutes and other similar interior workings may be established, and their designations marked within the main longitudinal workings; but, where they are thus marked, certain symbols may be discarded for the sake of brevity, and only such as are essential to the description of the working be employed. Thus, the raise at point Ar(0N84) (9W48) of Fig. 2 could be marked within the adit as r(9W48), and, indeed, such markings may be still further abbreviated when fixed within the mine. If it is desired to specify that this raise is both a chute and a ladderway, then may "c" and "l" of the legend be added to its description. The designations of raises carried through from different levels at equal distances from the transverse datum-plane would exhibit the fact. Thus described and marked, there is no possibility of duplicating the number or designation of interior workings.

In the taking of a series of samples, the scheme may be made to describe not only the designation of each sample of the series and its width as well, but the exact location of the point from which they were taken. Samples taken from northward of the longitudinal datum-plane are numbered and measured towards the north, while those taken southward of that plane are numbered and measured towards the south. One or more samples taken from across the width of stopes above a particular point of a drift or other longitudinal passageway is, for convenience, referred to that point of the passageway with regard to the transverse and longitudinal designation thereof. The following list of samples assumed on the maps, Figs. 1 and 2, will sufficiently explain the workings of the system:—

Number of Sample.	Designation of Working.	Location.			Width of Sample.
		Transverse Planes.	Longitudinal Planes.	Horizontal Planes.	
18	A–B Int. 1d	(1N15)	(8W30)	....	5.
19	A–B Int. 1s	(1N15)	(8W70)	(0P40)	7.
20	Aa	(0N80)	(2W04)	....	8.
25	As	(0N80)	(3W55)	(0P60)	3.
26	As	(0N83)	(3W55)	(0P60)	5.
42	1d	(0N20)	(3W26)	....	6.
43	1d	(0N26)	(3W26)	....	7.
44	1d	(0N33)	(3W26)	....	4.
46	1s	(0N20)	(3W26)	(0P50)	12.
73	2–4 Int. 1d	(0S60)	(7W20)	....	5.
93	5d	(1S68)	(3W92)	....	5.
94	5x	(1S73)	(3W92)	....	15.
99	5s	(1S56)	(3E30)	(0P50)	6.

For example, the last sample would be written 99–5s(1S56)(3E30) (0P50)6.

The above reference scheme for numbering and naming points and parts of mine-workings can be applied to the workings of any and all other classes of mineral-deposits, with such variations in its details as may be necessitated by changes in the methods of developing and operating such other deposits. In flat veins the side of a drift or other longitudinal passageway that is toward the dip of the vein may be made the plane of division between the various levels of the mine and between the blocks of ore belonging to those several levels. In mass- or pocket-deposits of large extent and irregular occurrence, and in connection with bodies of ore that occur in the form of more or less irregular lenses, the plan above described may be of the greatest advantage in blocking-out the ores for purposes of description and localization, and it may be employed with great benefit in connection with the mapping of square-setted stopes. In the development of such bodies, and in operations connected with the winning of the valuable mineral products thereof from their places of deposit, for the sake of simplicity the various transverse and longitudinal horizontal passageways, or those which in the scheme under such conditions are arbitrarily assumed to be transverse or longitudinal workings, might well be made to coincide with the series of transverse and longitudinal planes which we have explained above.

SUBJECT TO REVISION.

[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

Piping in Steel Ingots.

BY N. LILIENBERG, PHILADELPHIA, PA.

(Bethlehem Meeting, February, 1906.)

DURING the past few years, the requirements for steel have been raised so high that soundness is more important than ever before. The old practice was to make steel ingots of sufficiently large sections to permit a considerable reduction of area in rolling and hammering to a given size, relying on the fact that by such rolling and hammering all cavities will be squeezed together and practically eliminated. The finished sizes, if found by inspection of the surface to be faultless, were therefore pronounced to be sound. But when such steel is "worked up," the manufacturer is surprised and disappointed to find that it splits, or that streaks and seams make the product unmarketable. Large sections, such as rails, beams or heavy forgings, may, within certain limits, be sufficiently strong, even if the sides of the cavities are only squeezed, and not welded together. But it is well known that, in the interior of heavy articles, under certain conditions, forging may develop small streaks into large cavities. Small sections, steel for ordnance and tubes, and numberless articles in the tool-trade, always show up the defects. It may be doubted whether cavities in steel ingots can ever be completely welded. The old theory is, that the silver-clear blow-holes, without the blue oxide, can be welded by sufficient working. They are, however, not empty, but are filled with carbonic oxide. It is admitted that the "blue" cavities, resulting from air mechanically drawn down into the mold during the casting, can never be welded, because the oxide does not melt, and there would be no escape for it if it did. The only way in which steel can be made satisfactory for the above-named particular purposes is by having it "dead molten." But then the trouble of piping is encountered.

As is well known, a pipe is the result of the contraction of the liquid interior after the surface of the ingot has become solid by contact with the mold. When this contraction is partly taken up by blow-holes, there is, of course, less sinking of the metal at the top. The soundest steel, therefore, has the worst pipe. Some manufacturers having found that, for certain purposes, piping is a worse evil than blow-holes, are, therefore, purposely casting honey-combed ingots. Several manufacturers rely on casting steel at such a temperature that the blow-holes arrange themselves in a zone midway between the center and the surface, thus making the defects invisible after rolling or hammering. But, aside from the impossibility of always arranging the gas-bubbles in this way, the defects will afterwards appear in working, as above mentioned. The pipe is always coated with blue oxide from contact with the air. This oxide is formed instantaneously; and therefore the common practice of filling-up the pipe with liquid steel during casting and solidification only forms a stopper which is not welded to the ingot.

A great many processes have been invented to obviate piping. Those of importance may be arranged in two classes: keeping the steel liquid, and compression of the steel.

I. *Keeping the Steel Liquid as Far Out Towards the Mold as Possible, in Order to Get an Even Sinking of the Top Surface.*

All methods working on this principle suffer from the evil that, the period for solidification being prolonged, the separation of the impurer, and therefore lighter, steel has more time to take place, and the segregation will be more pronounced. Under this heading the following methods may be mentioned:—

1. *Addition of Aluminum*, either in the ladle or in the molds. The aluminum increases the heat by combining with part of the dissolved oxygen, and, at the same time, lowers the melting-point of the steel (which, of course, works in the same direction). It is well known, however, to-day, that aluminum does not realize the expectations formerly entertained concerning its use. It makes somewhat sounder steel, but it does not prevent piping; and it has been found, in many instances, to have the tendency to throw a bridge of solid, sound steel over the top of the ingot, thus hiding a large unseen cavity in the interior.

2. *Addition of Thermite.*—This mixture of aluminum and

iron oxide gives a greater heat than aluminum alone, on account of the extra supply of oxygen present; and its use makes the steel in the mold fairly sound. But, inasmuch as the higher temperature cannot prevent the steel from solidifying first in the outer layers, a pipe will nevertheless form, although it will be somewhat smaller.

3. *Use of Clay-Lined Funnels.*—These, placed on the top of the molds, shorten the pipe, because the steel does not chill so rapidly against the less-conductive clay as against the bare mold. The upper part has then to be carefully cut away so far down as to leave no part of the pipe. The exact distance from the top, at which the ingot should be cut, is somewhat difficult to determine, both in this case as well as in the common practice of cutting-off the upper part of the ingot and leaving only the lower part for use. In both cases the production is burdened by the considerable cost of fuel, labor and waste involved in remelting the upper or "piped" portions of the ingots, or of selling these portions at the scrap price, which is below cost.

4. *Casting by Overflow from One Mold to Another.*—In this method the molds are arranged in a row close to one another; and while tolerably sound ingots are obtained, there is the disadvantage that much scrap is formed by the steel running through the conduits. It is also obvious that the steel coming to the last mold is much cooler than that in the first.

5. *Use of Electricity.*—This method has sometimes been used to heat the upper part of the mold, and thereby prevent the chilling of the steel in contact with the sides before the center gets solid.* It is obvious, however, that, in order to be effective, the heat would have to be so great that the mold would be destroyed by the steel which would readily attack the walls. Moreover, the method is considerably more costly than that of cutting off the piped part.

II. *Compression of the Steel in the Molds.*

Much has been said and written about liquid-compressed steel, and the general opinion seems to be that, aside from the obliteration of the pipe, little or nothing is gained by compressing liquid steel, which is absolutely sound and "dead" molten. Since liquids in general are inelastic, and therefore incompressible, the possible degree of compression for liquid steel depends on the included gases. If the press is arranged so that these gases, which are elastic, have no avenue of escape, the effect of the compression will only be to leave cavities of smaller size. I need hardly say that the compression of liquid steel in the mold has quite a different effect from that of forging the ingot afterwards. In the latter case, the object is to change the structure of the steel at the same time with its shape. Among the numerous devices for compressing steel in molds the following three methods may be mentioned.

1. *Pressing from the Top*—While there is no difficulty in this method, if the whole charge goes into one mold, the machinery will be considerably complicated if several ingots of smaller sizes have to be cast. These ingots will have to stand on trucks and move in procession under the press; or several presses will have to be arranged with additional complications. It is almost impossible to time the casting and the pressing in harmony. If the latter is done too early, the cavities will continue to form in the interior of the steel. If too late, the pipe is already formed and oxidized, and therefore will only be squeezed together, but not eliminated. Any compression from the end of an ingot is attended with the danger of tearing the interior loose from the surface. This process is in use in some places in England and Germany.

2. *Compression from the Bottom.*—This idea originated in practice at St. Etienne, France; and the process is in use at several French works. It naturally suffers from all the disadvantages of the top-compression, and, in addition, the hydraulic machinery is contained in a deep pit, which makes it difficult to be cared for, and also exposes it to slag, dirt, and accidental spirts or leaks of liquid steel. In both cases the molds have to be made sufficiently strong, and correspondingly heavier and more expensive. It is, of course, a special and simpler case where the whole charge is poured into one mold, as, for instance, in making a gun of large size.

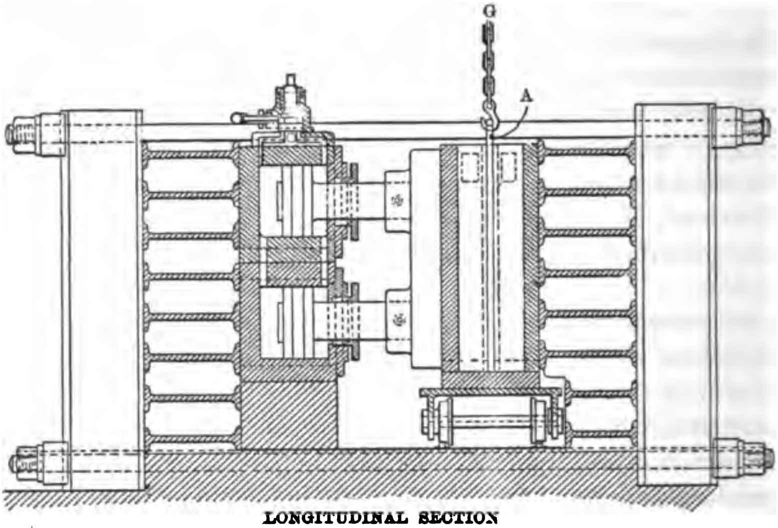
3. *Compression from the Sides.*—In this method the top is left open, permitting the gases to escape, and the pressure is applied directly in proportion to the formation of the pipe, so as to keep the ingot always full to the top. It is obvious that the pressure can be better timed in this way than in the preceding cases.

Some years ago an apparatus of this kind was built in Pittsburg, having four slowly-moving rollers in the same plane. The ingot, with liquid interior, was taken from the mold and placed between the rollers; and as it slowly moved downward the compression kept the liquid steel toward the top, and prevented the formation of pipe. This is undoubtedly the right principle; but it encounters the insurmountable practical difficulty of transferring the semi-liquid ingots from the mold to the rollers, where they are also liable to be warped and twisted. Moreover, if liquid steel be shaken, it is liable to become honey-combed by the escape of part of the gases dissolved in it.

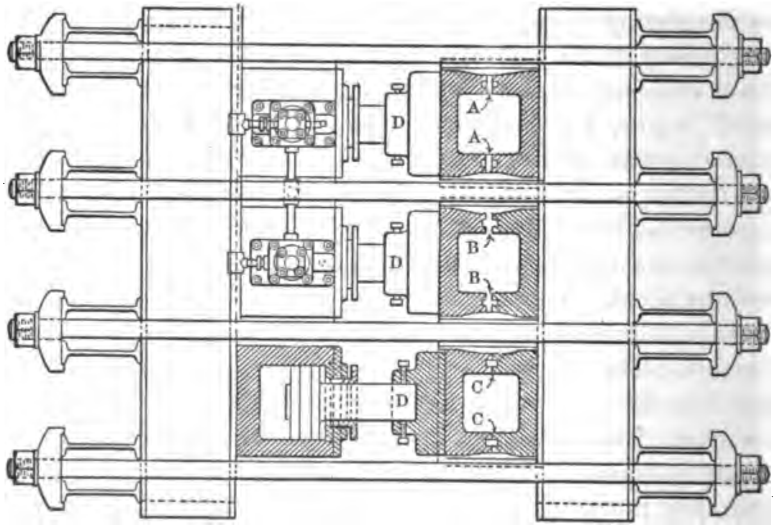
Side-compression in a stationary mold, having none of the objections above mentioned, is now successfully carried out, even with the largest-sized ingots. This has been mainly accomplished by Mr. John Illingworth, who, for a long period, has devoted his large experience to the practical solution of the problem, and has obtained many patents in this field.

Mr. Illingworth began by casting a continuous ingot through a prolonged vertical mold, the lower half of which was cooled by circulating water. The ingot dropped down through the bottom-less mold and was broken-off by a hydraulic clutch while still red-hot. This method, which worked very well for small ingots, presents difficulties for the larger sizes. The second group of Mr. Illingworth's inventions comprises casting-machines, built on the principle of hydraulic rams, which squeeze the two halves of the mold slowly together after they have been sufficiently opened to enter a plate between the ingot and the mold. This plate, having the section of a segment of a circle, displaces a corresponding volume of the semi-liquid interior. The two halves of the mold are drawn apart as soon as a thin skin is formed, holding the liquid steel during compression. The movement of the molds, which are placed close together, is made by draw-bars connected with the head of the hydraulic rams. This apparatus has given very satisfactory results for small ingots cast from crucibles, but it is not well-adapted for casting from a bottom-tapped ladle into large molds. A special apparatus on the same principle was built for this purpose, but the experiments were not continued sufficiently long to secure successful results.

The problem of compressing large-sized ingots, cast from a ladle, is, however, now completely solved. Mr. Illingworth, together with Mr. S. Robinson, has built such casting-machines



LONGITUDINAL SECTION



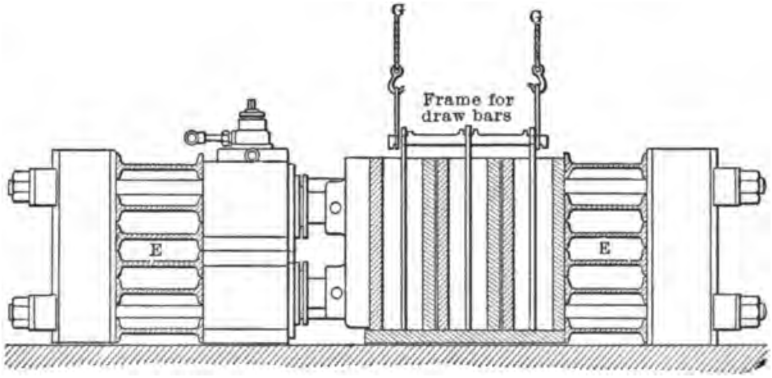
PLAN

FIG. 1.—ILLINGWORTH CASTING MACHINE FOR LARGE INGOTS IN MOLDS ON WHEELS.

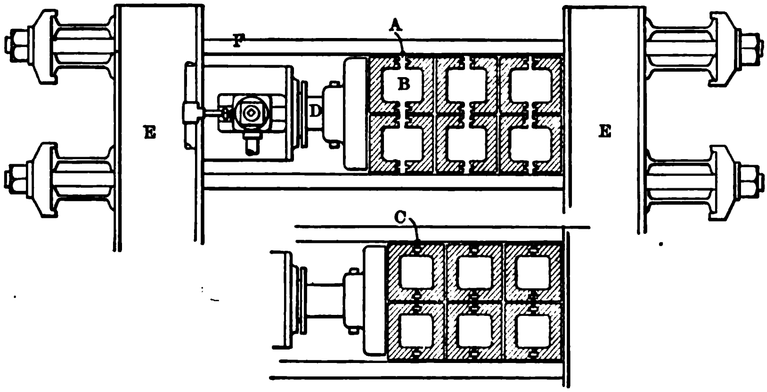
at the steel-works of Jessop & Sons, Sheffield, England, which uniformly turns out ingots of the largest size, absolutely solid from top to bottom.

The half-tone photograph of split ingots, Fig. 4, showing one with pipe, *A*, and another which has been compressed solid from end to end, *B*, is both interesting and convincing.

There are two kinds of casting-machines, one for large and the other for small ingots. Figs. 1, 2 and 3 illustrate the construction and working of these machines, which are covered by U. S. Patent No. 810,654, issued Jan. 23, 1906. The principle is to cast the steel in molds divided in halves and held together, during the casting, by hydraulic pressure. In the planed side-edges of the molds are grooves which admit bars of a cross-section shown at *A*, Figs. 1 and 2. After the metal has been poured into the mold, sufficient time is allowed for a crust to form while the interior is still liquid. The bars are then withdrawn by chains, *G*, suspended from an over-head hoist, which



LONGITUDINAL SECTION.

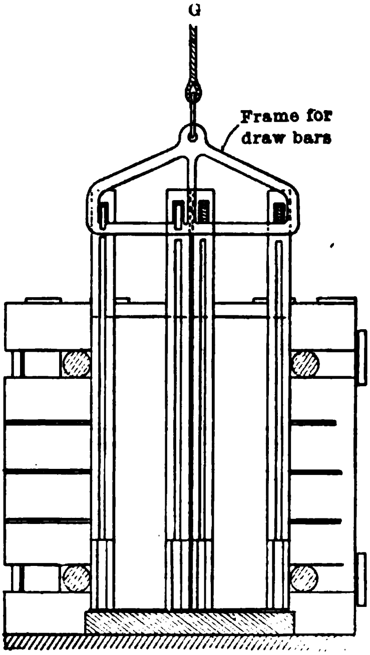


PLAN.

FIG. 2.—ILLINGWORTH CASTING MACHINE FOR SMALL INGOTS IN GROUPS.

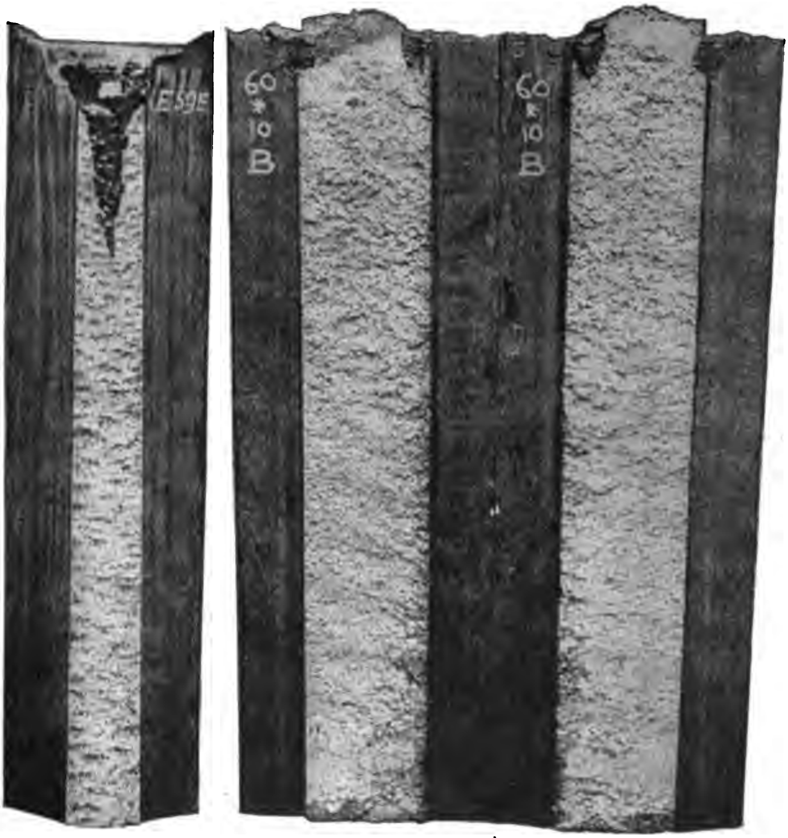
leaves an empty space between the two halves of the mold, as shown at *B*. Hydraulic pressure is then applied from the ram, *D*, and the outer half of the mold is moved forward slowly, so that the liquid interior is always kept full to the top until the mold is closed, as shown at *C*. The volume of the bars correspond as near as possible to the volume of the cavities which would otherwise be formed.

The large machine, shown in Fig. 1, is for large ingots cast on trucks, which are transported out of the foundry immediately after casting, each ingot to be compressed separately. This action can be so modified that three 2-ton molds can be compressed at one time.



TRANSVERSE SECTION.
(Scale double that of Fig. 2.)
FIG. 3.—ILLINGWORTH CASTING MACHINE FOR SMALL INGOTS IN GROUPS.

The small machine, illustrated by Figs. 2 and 3, is designed to compress ingots of smaller sizes that are cast in groups on the ground. In this case the casting must be made simultaneously in all the molds in order to have the same initial temperature. This effect can be done either by bottom-casting or by pouring the steel from the ladle through an under hanging-trough provided with a hole for each mold. With bottom-cast ingots the gates break off during the movement of compression. These illustrations have been prepared more for demonstration than for working-drawings. For clearness, several details of construction have been omitted. These details have to be modified to suit each particular case.



A
Cast and cooled in ordinary solid mold. Shows piping at upper end.

B
Cast and compressed in sectional mold during cooling. Shows absence of piping.

Fig. 4.—Steel Ingots Split Longitudinally to Show the Elimination of Piping by Compression During Cooling.

The hydraulic cylinders on the one side of the press and the back of the molds on the other are supported by six I-beams (*E*, *E*, in Fig. 2) laid horizontally on pieces formed to fit them, and held together by vertical beams and screw-bolts.

In regard to the details of working the Illingworth press, 3 or 4 men can cast and compress 6 ingots, 13 in. square and 40 in. long, in an hour's time. The edges of the molds have to be planed, but a mold can be used for about 125 heats before this repair is needed.

It is impossible to give general statements of the cost of operating this press, since the economy would have to be calculated for each particular case.

By careful investigation it has been shown that:—

1. During compression the surface of the ingot is neither crushed nor folded, but is merged in the mass, the same as in the roughing-mill, although the circumstances attending compression are not so favorable as those of rolling.

2. No groove is formed between the joints of the mold. If, for special steels, there should be some tendency to this, it is easy to make the edges of the bars slightly convex, thus leaving concave grooves in the ingots, which, by compression, straighten out to a plane.

SUBJECT TO REVISION.

[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

Improvements in Rolling Iron and Steel.

BY JAMES E. YORK, NEW YORK CITY.

(London Meeting, July, 1906.)

THE honor so fairly earned and so incompletely and tardily paid to Henry Cort, the inventor of the puddling-furnace and the rolling-mill, has been fully set forth by Mr. Charles H. Morgan,[1] and needs no further emphasis here.

In view of the importance of the rolling-mill in the treatment of iron and steel, the paucity of information concerning it is surprising. With the exception of a book, written about 35 years ago, by Peter Ritter von Tunner, an Honorary Member of this Institute, and of desultory articles on simple sections, which have appeared in technical journals, I know of no publication attempting to treat this subject, although volumes have been written on the scientific theory and technical manipulations involved in other branches of the iron- and steel-industry. This strange anomaly may be due to the fact that roll-turning cannot be called a scientific business. It does not ordinarily come within the range of an educated engineer; yet it cannot be performed by an ordinary mechanic. It demands some of the qualifications of an engineer, in designing, and those of a mechanic, in execution. The men who have followed this trade have controlled the training of their successors. In many cases the technical knowledge required has been handed down from father to son, and there has been a motive of private interest to prevent its public dissemination. Moreover, the statement of the various principles involved in the process would require, besides manual experience, a degree of scientific knowledge which roll-turners do not usually possess; and, finally, any book on the subject, in order to possess real, practical value, would have to be so fully illustrated as to make it very costly to publish.

Regarding my own experience, I may say that I served a six-year apprenticeship at the trade of roll-turning at Wednesbury, South Staffordshire, England, and, later, accepted a position as head roll-turner, believing that I fully understood the technical points of the business; but, after a short time, I realized that, if there were any theories governing the practice, I still had to acquire them.

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[1] "The Case of Henry Cort," *Trans.*, xxxv., 893 (1905).

Forty years ago, the bulk of the metal rolled was iron. Rolling iron was in some regards simpler, and in other regards more difficult, than rolling steel. Iron was adapted to quicker reduction, being softer, and capable of sustaining greater heat without injury. It was inherently weaker than steel at a rolling-temperature, even when properly heated; but piles could be made, conforming to the finished section, which was a great advantage in making flange-sections.

In the early stages of this business, the market called for simple forms only, such as flats, rounds and squares; but with the advent of railroads, and other commercial demands, it became necessary to roll more complex sections, such as rails, beams, channels and tees, which added very materially to the difficulties in the art of roll-designing. These difficulties I will attempt to explain.

Fig. 1 illustrates the rolling of a flat 6 in. wide and ½ in. thick. This was undoubtedly the first rolling ever done in grooved rolls, and represents the simplest section that we have to make, and the only shape, rolled in closed grooves, to which the principle of uniform flow of metal from rolling-contact can be applied.

It is recognized by all experts that metal flows under pressure in the direction of least resistance, which, in rolling, is at right angles to the journal of the roll, or lengthwise of the bar. The result is to make the bar stronger longitudinally than transversely; and this is true of every bar (except rounds and squares), either of iron or steel, rolled in grooved rolls. In some cases, the difference amounts to from 10 to 15 per cent. of the strength.

The most important physical effects are produced on the metal during the last stages of rolling. As the temperature decreases and the section becomes thinner, greater resistance is offered to reduction, and there is, consequently, a greater "fining" of the grain in steel or the fiber in iron. It is well

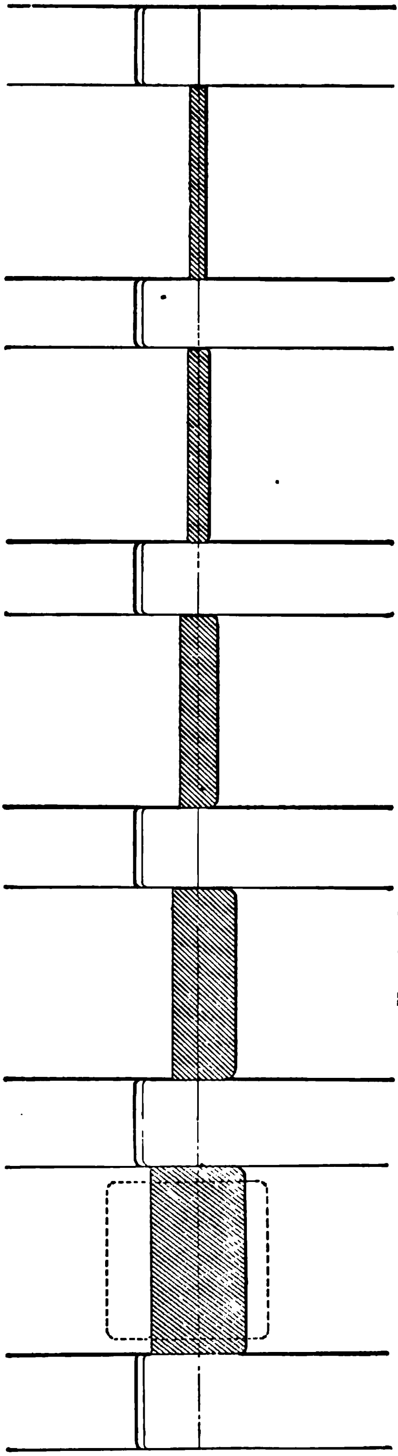


Fig. 1.—Showing Method of Rolling a 6-in. Flat.

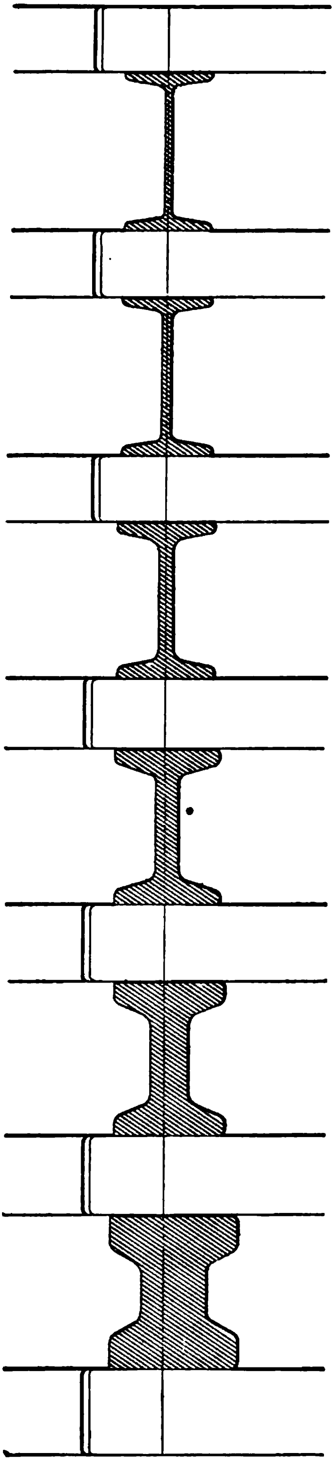


Fig. 2.—Showing Method of Rolling a 6-in Beam.

known that in large ingots there is scarcely any "fining" of the grain by rolling, and that this effect is only reached when comparatively small dimensions have been attained. (Of course, the result is influenced also by over-heating, and by the chemical composition of the metal.)

The only important modern change in the process of rolling is the addition of a third roll, which doubles the capacity of the mill, and constitutes the "three-high system."

The billet or ingot, from which any flanged section is rolled in an ordinary mill, must have dimensions practically equalling or exceeding the extreme dimensions of the section to be produced, although the actual area of metal in this section will be much smaller than that of the original mass. Moreover, the first shaping-groove must be wider than the mass, in order that the latter may enter it. It follows that the reduction of the metal by rolling-pressure is wholly in one direction; and this result is inseparable from the conditions presented by ordinary mills.

Fig. 2 shows how we rolled, "two-high," an ordinary 6-in. beam. Modern mills are "three-high;" but the same principle governs. This is one of the easiest flange-sections we have to roll, because it has an equal amount of metal on each side of the pitch-line, or center of the mill, and the flanges are of equal dimensions.

The difficulty encountered in rolling a section like this (and found to be still greater in sections of unsymmetrical form) is involved in the displacement of the metal from a square or flat billet, to form a web. This displaced metal runs to length; and since there is no commensurate reduction of the flange-parts of the section, the metal of those parts is liable to crack, because it is not rolled, but stretched. After the blank in the first pass has been filled out, a more uniform reduction of the various parts can be provided for. The finished section shown in Fig. 2 has a flange 3.33 in. wide, with a web about 0.23 in. wide—the latter having received a transverse reduction about twelve times that of the cross-section of the flanges.

The rolling of flange-bars involves the thinning of the flange sideways by forcing into the groove, metal much thicker than the recess provided. This is rather a wedging and drawing than a rolling action; and all such flanges are tapered, to permit their exit from the rolls. At the ends of finished bars of this character considerable waste is created by the different roll-dimensions, which prevent uniform surface-speed of the metal during the operation.

Another objection to this method of making flange-bars is, that it is impossible to distribute the metal in scientific proportions. In most of the beams rolled to-day by the prevailing method, the web is thicker by at least 20 per cent. than it need be, to harmonize with the other dimensions of the bar. The reason (if we take Fig. 2 as an instance) is, that the part of the roll which forms the web is 3 in. greater in diameter than the part which comes into contact with the widest part of the flange, and has at least 9 in. per revolution greater surface-travel than the part in contact with the end of the flange. The flange must, therefore, either slip or stretch, to accommodate itself to the larger diameter. This causes the web to buckle or corrugate when rolled down to the proper thickness. These difficulties are greatly increased in rolling wider-flanged sections, whether large or small in other dimensions. In fact, it is almost impossible to produce, in an ordinary rolling-mill, any shape with a flange equal in width to the total height of the section. The effect of the difference in surface-speed of rolling on various parts of rails, beams and other flange-sections, is, in my opinion, the cause of a large number of otherwise unaccountable fractures in service, due, probably, to permanent internal stresses rolled into the bar.

While engaged in the manufacture of iron beams about 30 years ago, it was suggested that, if beams could be rolled with wider flanges, greater height and thinner webs, at least 20 per cent. greater carrying-strength could be secured for a given weight. This led my brother and myself to design and build what is now known as the York universal mill, for rolling sections with wide flanges and thin webs, or the usual sections when desired.

The front elevation and plan of this mill, which is a radical departure from the process of rolling illustrated in Figs. 1 and 2, are shown in Figs. 3 and 4.

The advantages of this mill are:—

1. It dispenses with grooves entirely and gets uniform sections without this provision.

2. It eliminates the wasteful and difficult method of displacing metal to form a web which is out of all proportion to the other parts of the section.

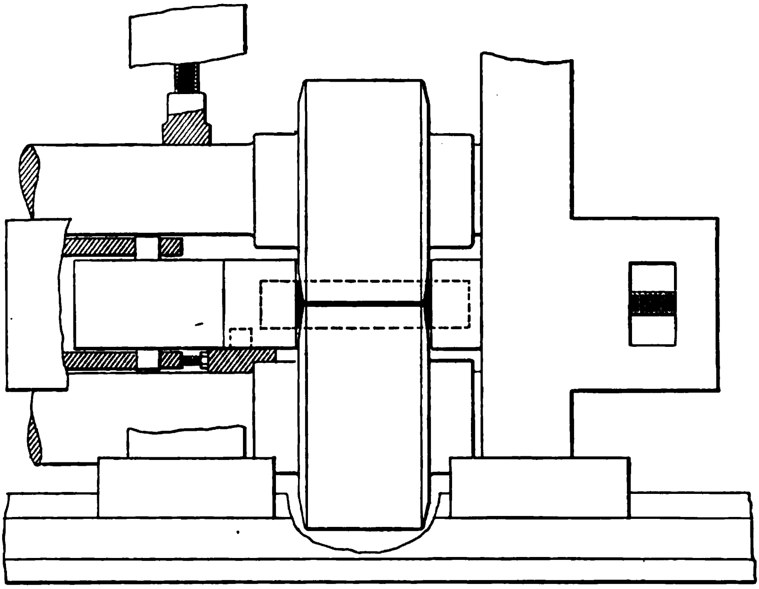


FIG. 3.—YORK UNIVERSAL MILL, SHOWING THE METHOD OF ROLLING AN 18-IN. BEAM WITH 6-IN. FLANGES.

3. No technical knowledge is required to design the rolls.

4. The operation is exceedingly simple, and the same rolls can produce a properly proportioned section weighing 50 or 150 lb. per foot.

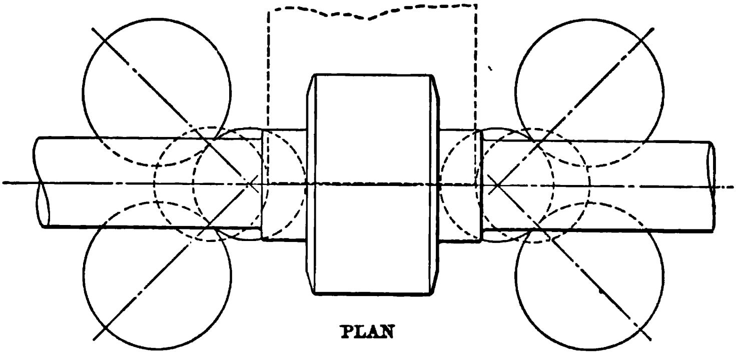


FIG. 4.—YORK UNIVERSAL MILL.

5. By the old methods the web increases in the same proportion as the width of flanges, which is a great waste of metal.

6. This mill is adapted to roll either scrap or new steel to sections at least 50 per cent. less in weight per linear foot than the common forms.

7. The beam produced by this mill has the same tensile strength transversely (where it is required) as in the longitudinal direction.

8. The rolls can be adjusted either at the commencement or during the operation, in order to have the web thinner and the flanges thicker, or the reverse.

9. This mill can roll a bar having one flange thicker than the other, since the dimensions of the flanges can be modified to suit requirements.

This mill consists of a pair of horizontal rolls positively driven, and a pair of vertical rolls run by the friction of contact against the bar. A line through the axis of these vertical rolls would intersect the center of the horizontal rolls.

The horizontal rolls work upon the sides of the web and shape the inner contour of the beam, while the vertical rolls shape the outer flange-surfaces. Both horizontal and vertical rolls are connected by a screw-device, so that the movement in all the rolls shall be simultaneous; an arrangement which secures the proper relative reduction of the flanges and the web.

Fig. 3 represents the rolling of an 18-in. beam with 6 in. flanges. The slab, or ingot, for making this section is 29.5 in. wide and 6.25 in. thick. These dimensions give a reduction on each flange of 5⅞ in. sidewise and a reduction on the web of 5⅞ in. at the same time, which produces a beam 18 in. by ⅜ in., having the usual taper to the flanges.

The rolls used in this mill weigh only one-quarter as much as those ordinarily used, and the power required is much less than that of the ordinary mill, for the reason that it is a rolling-process, both horizontal and vertical, instead of a partly wedging and stretching action, as shown in Fig. 2.

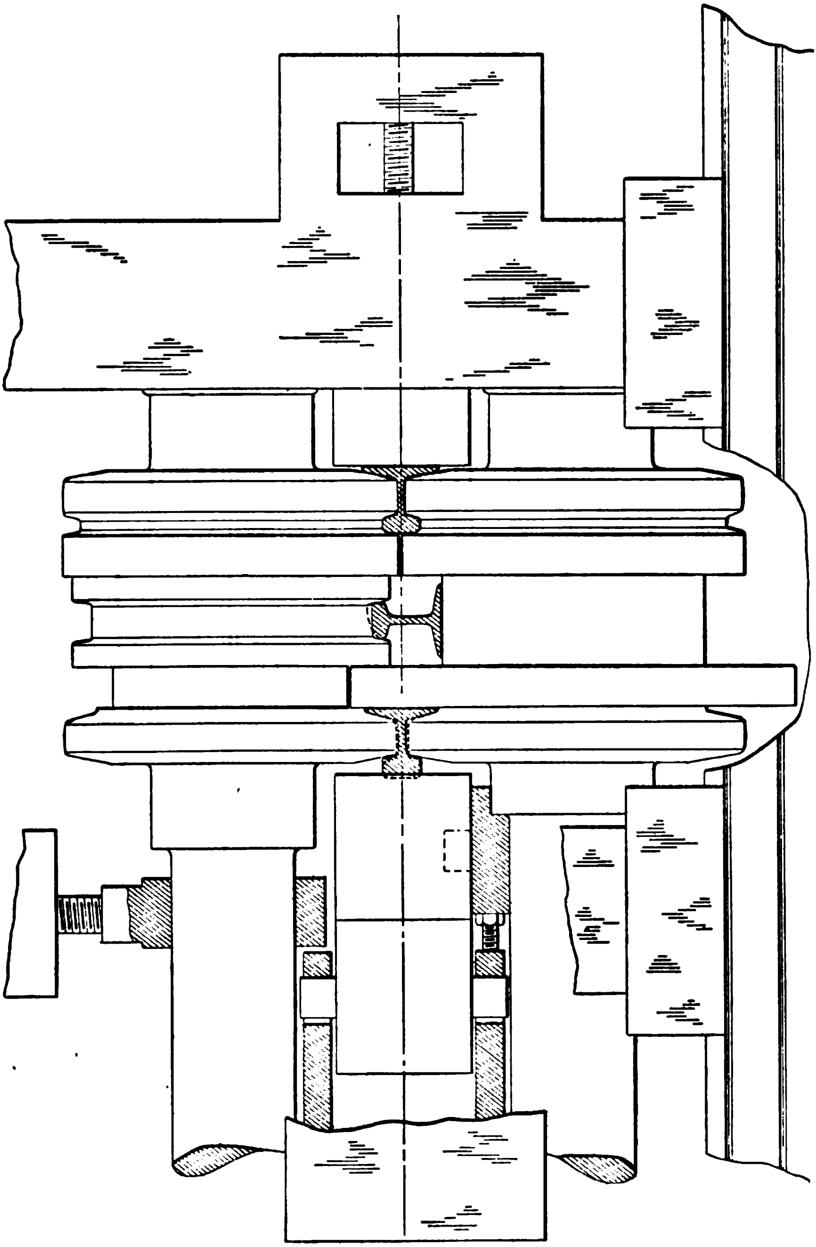
The mill is adapted, without changing rolls, to make any reasonable weight of beam, having wide or narrow flanges up to the width of the face of the vertical rolls. It also rolls tees of different dimensions having any length of leg, or flange, in the beam-rolls, the vertical rolls forming the flange. A beam-section cut longitudinally through the web forms two tees of half the height of the beam; hence a tee can be rolled on either side of the mill. Tee-sections, about the most difficult to roll in an ordinary mill, are very easily made by my process.

It was my intention, when building this mill on a commercial scale, to have a blooming-mill in which to roll an ingot down to about 3 in. thick in the web and a proportional thickness in the flanges; but, for unavoidable reasons, it became necessary to use the finishing-mill to do the entire reduction from the ingot or slab to the finished section. This action produced a slight defect in the finished product, the bars not being exactly parallel in the width of the flanges throughout the entire length. In order to overcome this difficulty, I proposed to use a pair of supplementary rolls to work on the edges of the flanges, these rolls to be placed in line of the main rolls, and to be run at the same surface-speed of delivery as the rolls in the mill proper. These changes have since been installed, and beams of perfect section are now rolled.

Our experience with this process in rolling beams, having the width of the two flanges greater than the height of the web, showed that it was necessary to feed-in the side-rolls faster than the horizontal; otherwise, in rolling light webs with wide flanges, there would be a buckling-action in the web, caused by the greater roll-surface contact on both sides of the flange. The mass being, of course, stiffer in the direction of the cross-section, the web was then held back to the average speed of the flanges, and caused it to corrugate.

The advantage of a light-web beam is illustrated as follows:—The 18 by $\frac{3}{8}$-in. beam, Fig. 3, weighs 42 lb. per ft., and the nearest comparable size of the ordinary beam is 15 by 0.41 in., which also weighs 42 lb. per foot. The ordinary beam, however, has a load-carrying capacity of 18 per cent. less than the light-web beam,—a difference which is larger in most of our sections, especially those made to take the place of built-up plate- and angle-girders, having a much greater weight per foot. In addition to the gain in strength, the cost of building-up is reduced; this cost, in some cases, exceeds 40 per cent. of the cost of our rolled beams. Sections having wide flanges which equal the height of the section (or nearly so), are intended to take the place of "Z" bars and other columns. In this case, also, there is a great saving in weight and cost.

This mill has also been adapted to re-roll rails of various types for further service in the track, as shown in Figs. 5 and 6. It is admirable for this purpose from the fact that the rolls



can be chilled, thus permitting the proper finishing-temperature required to secure the best physical results. This mill can also, upset metal from the web into the head and leave the flange the same width, and it can re-roll any flange-bar or other sections in a longitudinal direction.

Some years ago I took up the problem of making a steel tie, or sleeper, that would meet all railroad-requirements and, at the same time, be able to compete in cost with the wooden ties now in general use. To meet these conditions it was necessary to use worn scrap-rails for the raw material, since it must be obtainable at a low price and in large quantities.

First, I designed sections for a steel tie, which railroad engineers said were ideal, provided it could be rolled. Then I designed a mill, shown in Figs. 7 and 8, to change the dimensions of a rail without lengthening it in the rolling. This mill can be driven like an ordinary two-high plate-mill, or by disconnecting the top roll from the power, it may be run by frictional contact with the bar. The latter plan I consider to be the simplest and the best, for the reason that access to the mill can be had in all directions, by having a hydraulic motor connected with a rack in a pinion on the bottom roll. Both plans have given good results. The simplest method of all, however, is to connect a hydraulic motor between two mills, rolling in both directions, which naturally increases the output.

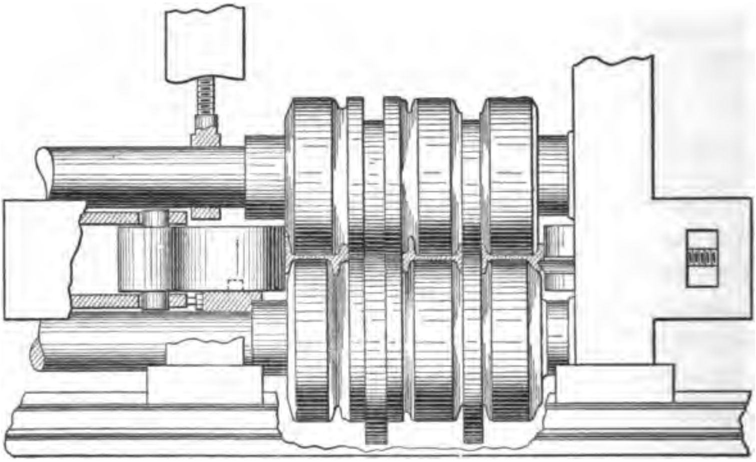
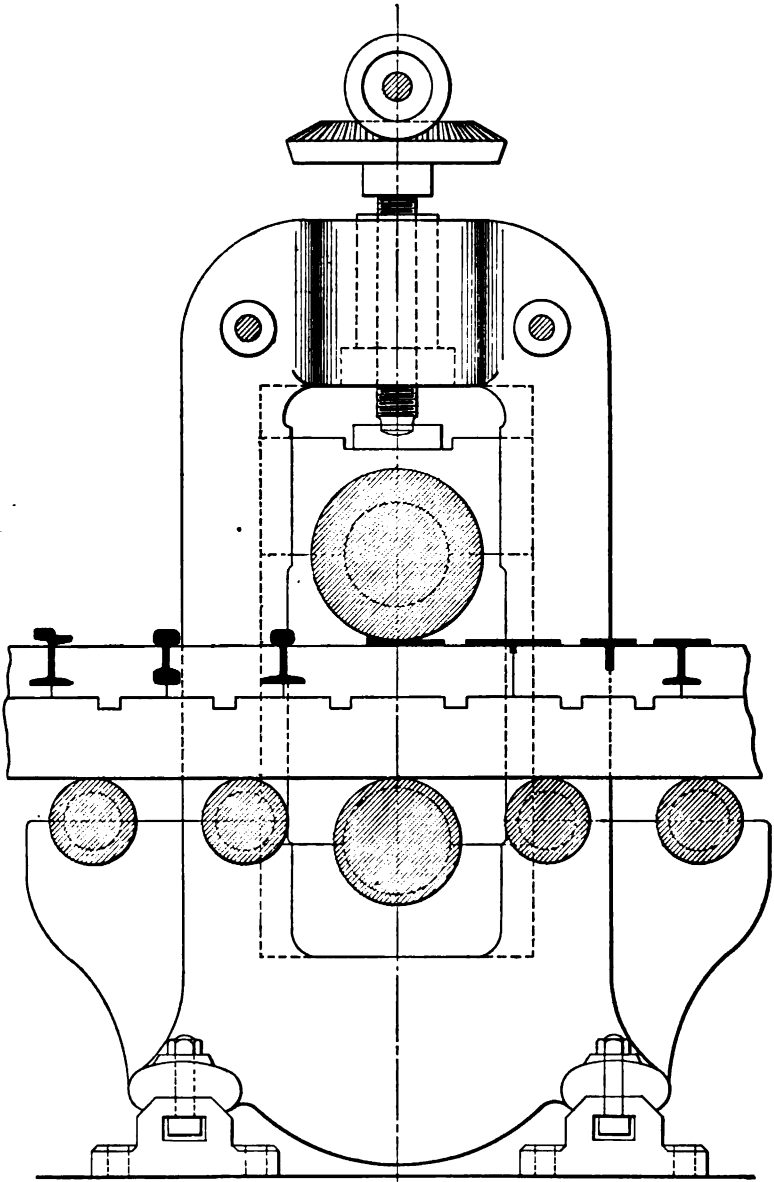


FIG. 6.—SHOWING THE METHOD OF RE-ROLLING A GIRDER-RAIL BY UNIVERSAL MILL.

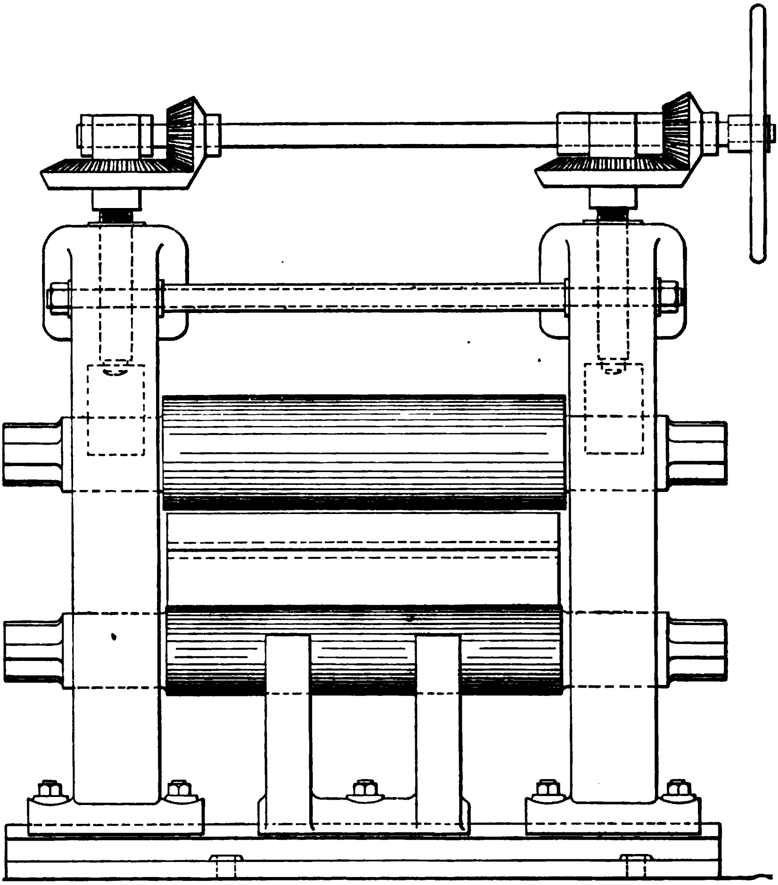
By all other methods the greatest difficulty in longitudinal rolling is to produce sections having wide flanges; but in my



END ELEVATION
FIG. 7.—YORK TRANSVERSE MILL.

mill this kind of rolling is very simple. One part of the bar is rolled without disturbing the other dimensions. Rails that have been used on curves and have lost one-third of the metal on one side of the head, can be rolled to form a section having the metal symmetrically distributed on both sides of the web, by using a rolling and bending action simultaneously in the mill, as is illustrated in Fig. 9.

In rolling steel rails by the ordinary process, the web and bottom flange receive the most physical work in the mill, and are finished much colder than the comparatively large mass of metal in the head. The head, therefore, is the weakest part of the rail. In re-rolling an old rail by my process, the head receives the greatest amount of physical work, and the finishing-passes can be made at a low heat, if desired, thus greatly improving the quality of the metal.



FRONT ELEVATION
FIG. 8.—YORK TRANSVERSE MILL.

The capacity of the mill, in tonnage, would be regulated by the number of bars rolled at one operation. There is no difficulty in rolling at least six bars at a time, which gives a safe estimate of from 150 to 200 tons per day, of rails weighing from 60 to 75 lb. per yard.

During the rolling of any section in this mill, the flanges can be made thick or thin without any change of rolls.

This mill is confined to the transverse rolling of lengths not exceeding, say, 10 feet. If greater length is desired, a bloom (either of scrap rail or new steel) is rolled to proportionate dimensions of cross-section, and then rolled to length in our universal mill.

Fig. 10 illustrates the mill rolling tees, tie-plates, column-blanks and double-headed rails. Fig. 11 shows the head of a worn 95-lb. girder-rail, having a part of the web attached, which is rolled to a width of 20 by ⅛ inch. Fig. 12 shows a T-rail section with the head rolled five times wider than its original dimensions. Fig. 13 shows a worn 70-lb. T-rail rolled down to a plain tie-section without changing the web or flange of the original rail. Fig. 14 shows the same weight rail rolled with a curved base to give elasticity to the tie under moving load. Fig. 15 shows the section with a curved seat for the rail, so as to ensure the elasticity of the tie if the ballast in contact with the curved base should interfere with the elasticity of the lower flange. Fig. 16 shows a beam with flanges 9 in. wide and 3.25 in. in height of section, rolled from a 70-lb. rail. Fig. 17 shows a section rolled with wide flanges, leaving the web without change of form. Fig. 18 shows a flange rolled on a 3 by 0.75-in. flat bar to six times the width of the thickness of the flat. Fig. 19 shows a column section rolled from a 70-lb. rail. Fig. 20 is an end elevation of this mill, which shows the rolling of flanges on large and small ingots and flat

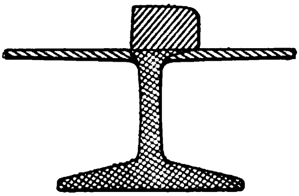


FIG. 9.—SHOWING THE RESULTS OF TRANSVERSE ROLLING.

slabs for blanks for the finishing-mill. This arrangement dispenses with the unequal displacement of metal to form the web, and removes the greatest difficulty in the rolling of flange sections, and makes possible the production of sections from new steel that it is now impossible to produce by present methods.

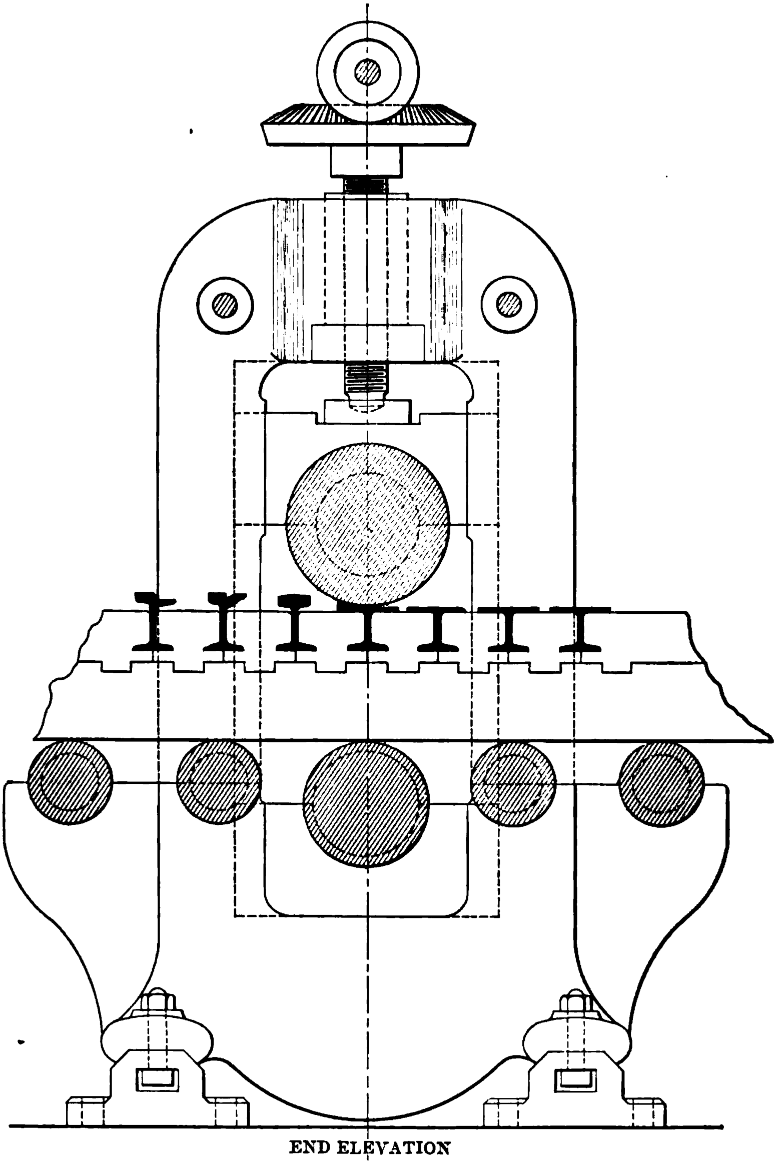


Fig. 10.—York Transverse Mill.

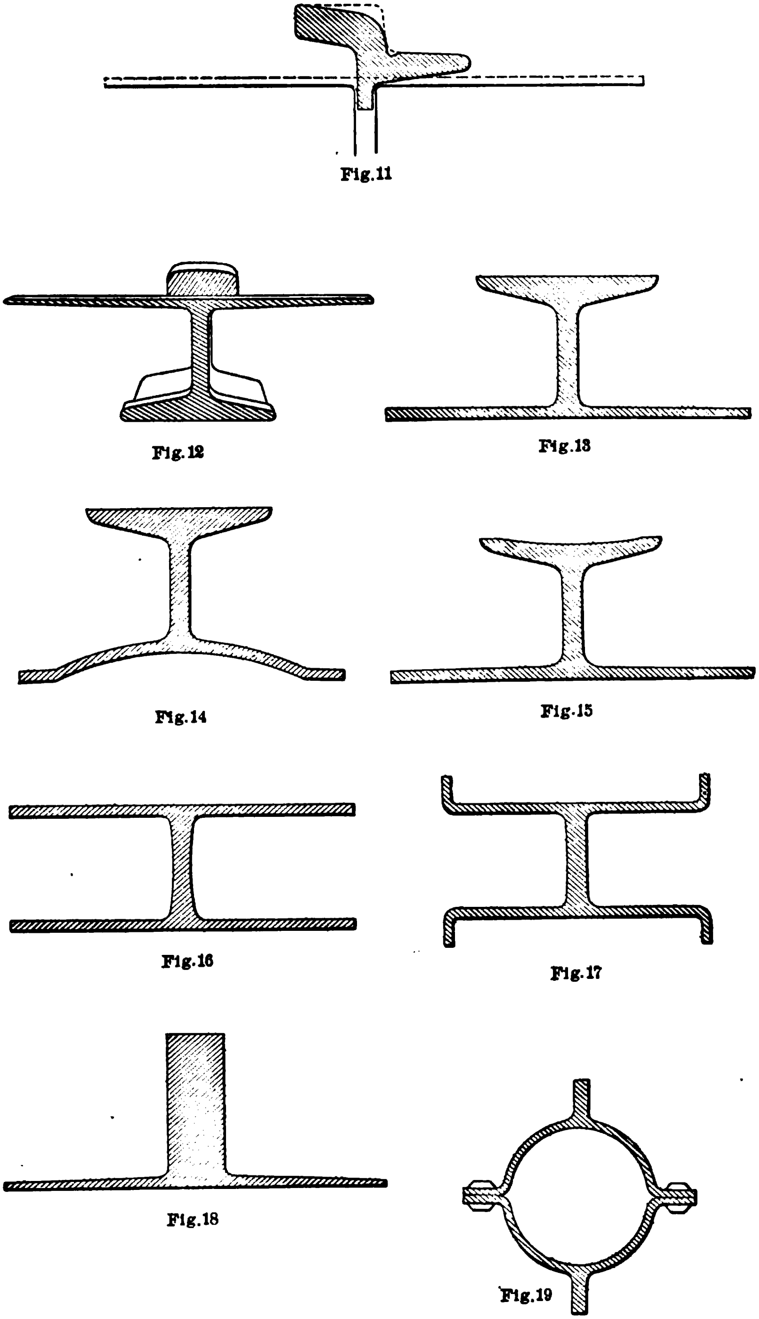


Fig.11

Fig.12

Fig.13

Fig.14

Fig.15

Fig.16

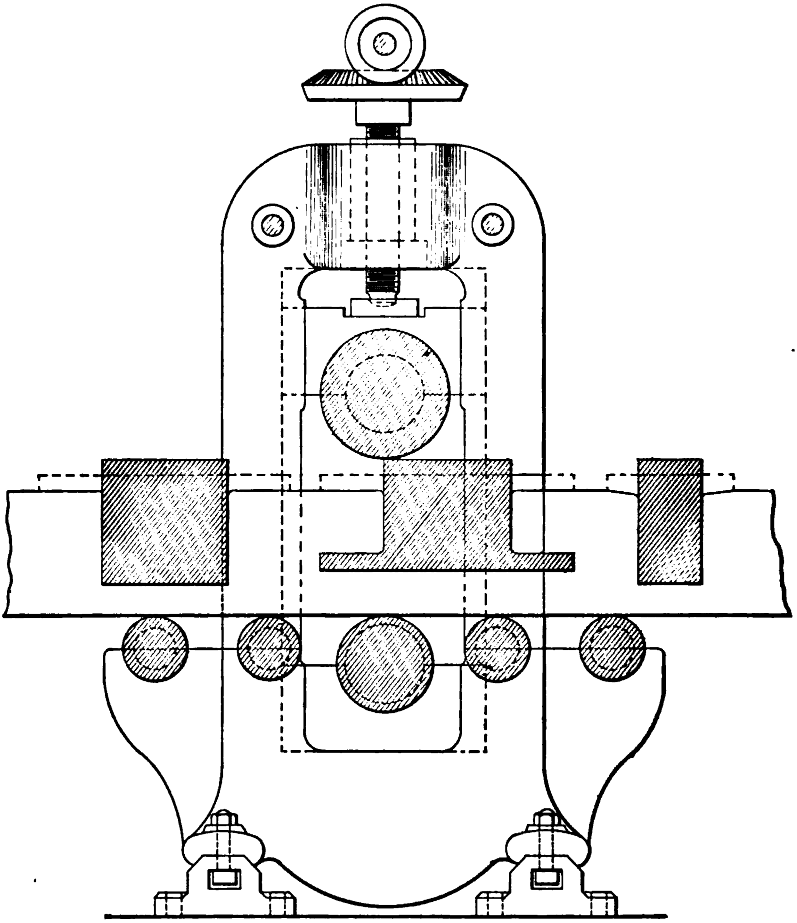
Fig.17

Fig.18

Fig.19

Figs. 11 to 19.—Special Sections Rolled by Transverse Mill.

Fig. 21 shows some of the various sections, rolled from rails, to be used for columns, telegraph poles, trolley poles, beams, fence posts and other purposes. To produce these sections it is necessary, first, to roll in a transverse direction to get the proper dimensions, and then to bend in the mill in a longitudinal direction.



END SECTION.

FIG. 20.—YORK TRANSVERSE MILL FOR ROLLING FLANGES ON INGOTS.

The following shapes can be rolled by using the mill for transverse rolling and longitudinally for bending hot:—Fig. 22, a rail with the flange and web unchanged from the old rail, and the head rolled into the shape given. Fig. 23, a similar section rolled with part of the web removed. Fig. 24, a section

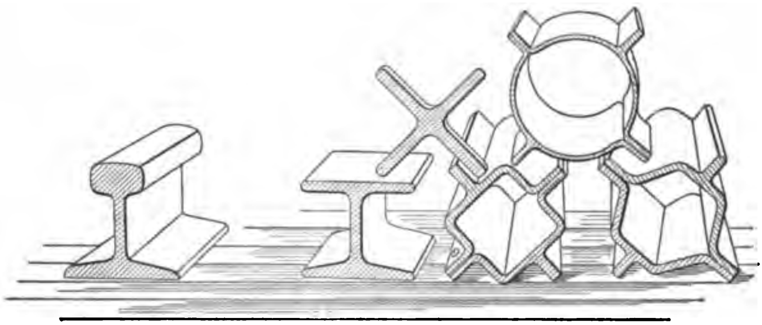


Fig. 21

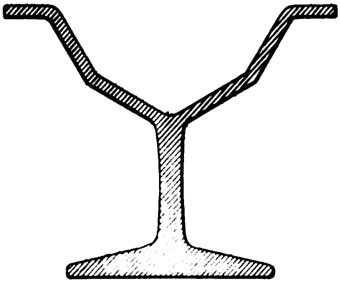


Fig. 22

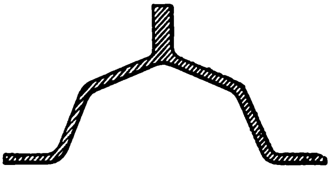


Fig. 23

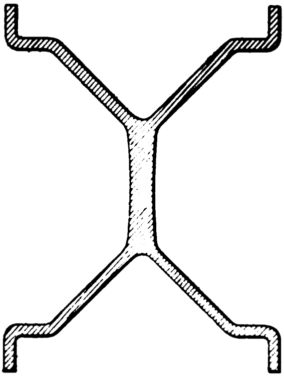


Fig. 24

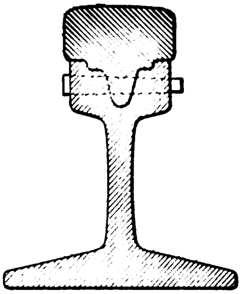


Fig. 25

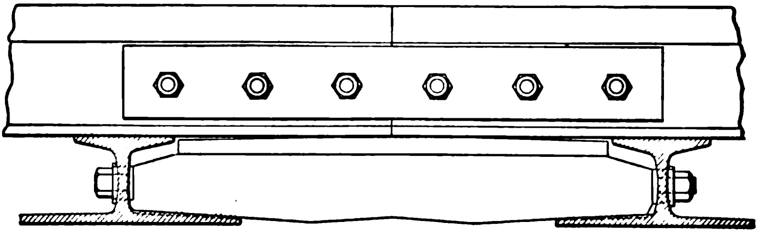


Fig. 26

FIGS. 21 TO 26.—SECTIONS ROLLED BY TRANSVERSE MILL.

where the rail-head and flange have both been rolled to the necessary width and then bent to the shape longitudinally. Fig. 25, a suggested base for a rail with a movable head. Fig. 26 shows a side view of a rail-joint, made from short pieces of worn rail. This joint is designed for the purpose of meeting any demands of adjustment, strength and cheapness. Fig. 27 shows a tie with a recess rolled to form a rail seat so as to prevent track-spreading. Fig. 28, column-sections with rolled projections parallel to the length. These can be changed, if desired, into indentations or any other shape. Fig. 29 shows taper-sections of narrow or great width; could be used for many purposes. Fig. 30 illustrates the utilization of short pieces of rail to make the tie-plates now generally used with wooden ties. I show one only, but I have already designed eight sections that can be made by this method.

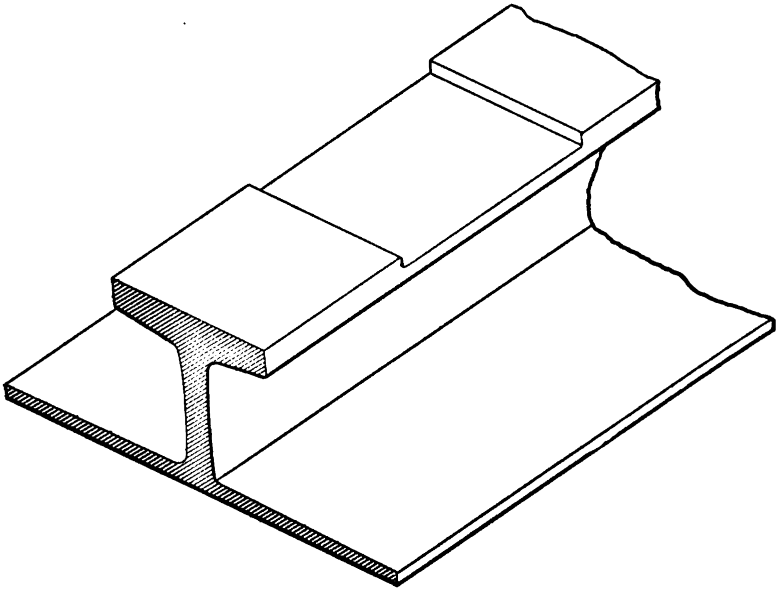


FIG. 27.—TIE-SECTION WITH RECESS FOR RAIL, ROLLED BY TRANSVERSE MILL.

All the sections described above, with the exception of the ingots shown in Fig. 20, are designed to be made from old worn rail-sections. The girder- and guard-rails of electric and street-car lines can be used to make the same class of material; and while the section would be of greater height, it is capable of being rolled with the same facility as worn tee- or double-headed rails.

The method is not confined to the use of rail-sections alone as material for re-rolling. We take beams of all sizes, split the two flanges off, hot, in the machine, and use them for T-sections, column-blanks and other purposes after re-rolling. Angles, and, in fact, bars of any kind, are similarly available. The presence of holes in scrap material does not interfere with rolling by this method.

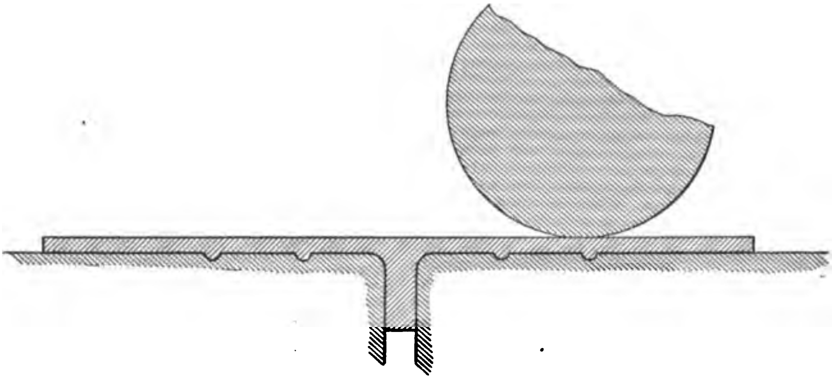


FIG. 28.—COLUMN SECTION WITH PROJECTIONS PARALLEL TO LENGTH, ROLLED BY TRANSVERSE MILL.

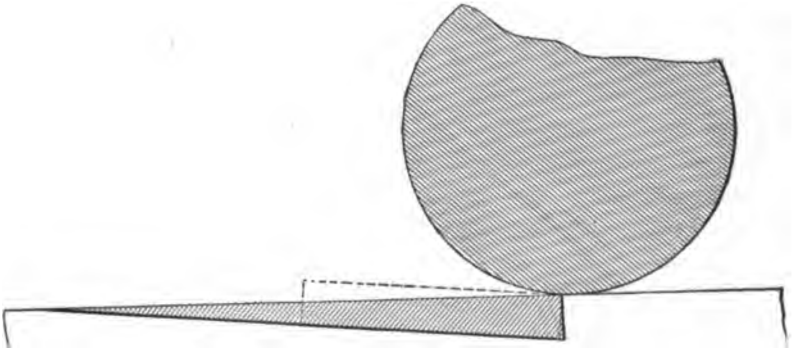


FIG. 29.—TAPER-SECTIONS, WIDE OR NARROW, ROLLED BY TRANSVERSE MILL.

Some of the many sections which can be rolled by this process are shown in the accompanying illustrations. I have already designed several hundred shapes that differ from existing sections, either in weight or design.

It is adapted for flanging plates and sheets, hot or cold, and for making angles from flats; also, for re-rolling plates and sheets with decorative designs on their faces, for artistic and industrial purposes.

In planning these mills I kept in mind the necessity of making them strong to resist the hard usage of rolling-mill practice; simple, so that they could be readily adjusted; and, also, capable of operating with unskilled labor, except that of the mechanic to run the machine and the heater to heat the material. The rails can be fed into the machine simply and quickly, and, when the rolling is completed, the hot bars push out, laterally, those already rolled. The functions of the machine are almost entirely automatic.

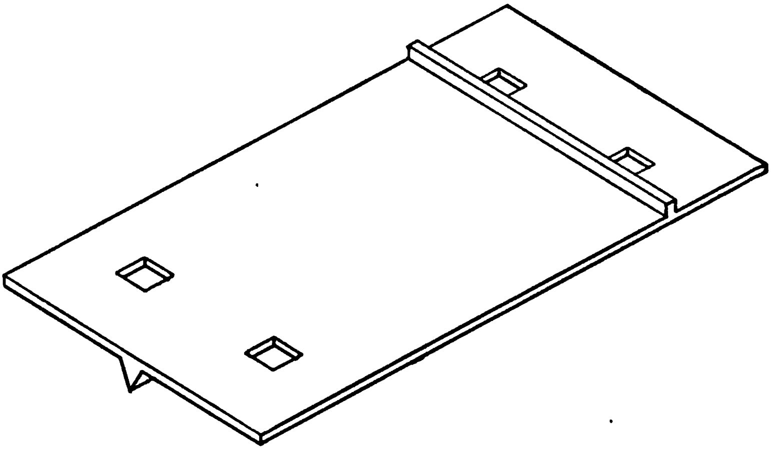


FIG. 30.—TIE-PLATE, FROM SHORT PIECE OF RAIL, ROLLED BY TRANSVERSE MILL.

The economic and commercial importance of the application of this method to the utilization of scrap for ties, joints and tie-plates has been well stated, as follows:[2]—

> "At the present time there are about 450,000 miles of railways constructed in the principal countries of the world. Of this mileage, probably 33 per cent. at least is double, counting the sidings, which would raise the total as single mileage to 600,000 miles. The weight of metal required in any system of iron or steel sleepers will, of course, depend mainly upon its form and method of application, but a conservative mean would probably be 100 tons to the mile of single line, which would give us, for the railways of the world, a possible supply of 60,000,000 tons, or, roughly, about 40 times the total output of Bessemer steel in Great Britain during the last three years. Clearly, therefore, if metallic sleepers were substituted for timber, the steel trade would profit enormously."

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[2] *Iron and Coal Trades Review*, April 10, 1896.

Since the above was published, the *Archiv für Eisenbahawesen,*[3] reports an increase in mileage, at the end of the year 1903, to 533,978 miles, which, including side-tracks, is equivalent to about 700,000 miles. Estimating on a basis of 125 tons of steel per mile of single track, the total quantity of steel used reaches the enormous total of 87,500,000 tons.

If, as I have attempted to show, these rolled bars can be made from material that has already fulfilled the purpose for which it was originally made—namely, its use as rails—a great economic advance will have been effected.

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[3] *Railroad Gazette,* June 30, 1905, p. 749.

Biographical Notices of 1905.

(Bethlehem Meeting, February, 1906.)

The list of deaths reported during the year 1905 comprises the following names (the figures in parentheses indicating the year in which the persons named were elected to membership:—

Honorary Member.—Dr. Bruno Kerl.

Members and Associates.—Charles Christy Adams (1903), John Wesley Anderson (1898), William Burton Barber (1901), Thomas A. Bennett (1900), Luke W. Bryan (1901), Edwin S. Daugherty (1905), William Scott de Camp (1875), George H. Eldridge (1889), B. W. Frazier (1871), John Broome Guinn, Jr. (1897), Dana C. Irish (1900), Harry Hugh Lee (1899), William Alfred Lindsay (1902), Roland C. Luther (1884), James MacNaughton (1890), Gordon McLean (1899), Herbert Holmes McNamara (1902), August R. Meyer (1886), William Orr (1897), William J. Parker, Jr. (1898), Joseph Phillips, Jr. (1895), Charles O. Ripley (1902), Emmerich J. Schmitz (1883), Ludwig Philip Seeger (1900), Jacob Johnston Sperry (1900), Gustavus H. Stoiber (1902), William L. Study (1905), Robert Macnair Wilson Swan (1900), Richard Henry Terhune (1886), Joseph Thiry (1892), John N. Tisdale (1903), Alfred Isham Totten (1897), Walter H. Virgoe (1902), Charles H. Wellman (1890), Harvey L. Williams (1903).

Of these, Dr. Bruno Kerl and Prof. B. W. Frazier have been made the subjects of special Biographical Notices in the *Bi-Monthly Bulletin;* the former in No. 4, July, 1905, p. 743, and the latter in No. 5, September, 1905, p. 1097. Concerning the remainder of the list, the following paragraphs comprise such information as could be obtained by the Secretary.

Charles Christy Adams, who had been a member of the Institute since 1903, died in Johannesburg, South Africa, August 31, 1905. He was born in New York City, July 13, 1849, and received his technical training at the Colorado State School of

Mines at Golden City. His professional labors included the following positions: 1883 to 1888, General Manager, Rosario Mining and Smelting Co., Salinas Victoria, Nueva Leon, Mexico; 1900 to 1903, U. S. Deputy Mineral Surveyor, State of Oregon, and Superintendent El Renacimiento Mine, Ocotlan, Oaxaca, Mexico (R. H. Hutton, General Manager); in 1903, Resident Manager, La Reforma, for The Reform Mine Syndicate Co., Ltd. (R. Hay Anderson, General Manager). In the latter part of 1903 Mr. Adams opened an office as consulting mining engineer in Mexico City. In 1904 he proceeded to London, England, whence, after making some business connections, he went to Johannesburg, South Africa. After about six months there he was about returning to America, when he was suddenly taken ill, and died in the Johannesburg General Hospital.

John Wesley Anderson, Vice-President and General Manager of the Carbon Steel Co. and Vice-President of the Union Steel Casting Co., of Pittsburgh, Pa., died at Harrisburg, Pa., on May 19, 1905, as the result of injuries received in a railroad train wreck at the latter place, shortly before. There was a party of five on the train,—Mr. Anderson, his son, Frank W. Anderson, Victor L. Crabbe, the Purchasing Agent of the Carbon Steel Co., Paul Bright, one of the company's engineers, and George Loeffler, their chemist. Young Anderson, Mr. Crabbe, and the senior Anderson died from their injuries. Mr. Anderson was well known in the steel trade, and was the patentee of a number of valuable steel-making processes. He was a life member of this Institute, dating from 1898, and also a member of the International Society of Testing Materials, and of the Engineers' Society of Western Pennsylvania.

William Burton Barber was born in Alameda, Cal., October 17, 1879. After preliminary education in the High School of that town, he entered Stanford University, where he was graduated in 1902, having made special studies in geology and mining. A geological trip through Nevada with Dr. J. P. Smith of Stanford was succeeded by a year's engagement as Assistant Superintendent of the Eureka quicksilver mine; after which Mr. Barber returned to Stanford University for a post-graduate course. At the same time he had an office in San Francisco, where he did much petrographic work for the State Mining Bureau and for engineers. In July, 1904, he became associated with the management of the Kennedy mine, Jackson, Amada Co., Cal., and was still in that employ when attacked by typhoid fever in the spring of 1905. He was taken home for care, but in vain. He died in Alameda, May 4, 1905.

Mr. Barber's interest in geologic research was keen and intelligent. He contributed articles on local conditions in British Columbia and in the Coast Range of California to the *American Geologist* and the *Journal of Geology*, and in many ways evinced both capacity and character. He joined the Institute in 1901.

Thomas A. Bennett, born at Salisbury, England, in 1843, died November 22, 1905, at Lima, Peru, and was buried in the Bellavista Cemetery near Callao, in the presence of many friends who had been attached to him during his honorable and useful career in that country. Mr. Bennett was well known as a mining engineer, usually preferring independent work to continuous employment. He had pursued his profession actively in the United States (especially in Utah, Nevada and Montana), New Zealand, Australia, Mexico, Chile, Colombia, and, for his last six years, in Peru—a land in which he became much interested, and for which he predicted a notable development.

Mr. C. Reginald Enock writes to the *Engineering and Mining Journal* as follows:—"He was much esteemed in Lima for his upright character and disposition, and his death is a loss to the country. . . . . The writer knew him for some years, and had been his companion in various expeditions into the Peruvian Cordilleras; for, notwithstanding his advanced age, Mr. Bennett was an indefatigable traveler. He represented important interests, both at home and abroad, and, as a result of his work, several large mining enterprises were under way in Peru, including the famous Cerro de Pasco copper-mines, which were first taken up on his initiative. It is for the writer a melancholy pleasure to pay this small tribute to the memory of a fellow-engineer and countryman, one who was always generous as an associate in business matters and loyal as a friend." Mr. Bennett's coworkers in many places testify to his sterling worth in the profession. He became a member of the Institute in 1890.

John Walter Best, who died in the city of Denver, Colo., August 20, 1904,* was born in Central City of that State, April 13, 1875, removing with his parents to Denver in 1887. His education was gained at the Denver High School; the State School of Mines, where he spent a year; and the Sheffield Scientific School of Yale University, which he entered in 1894, graduating in 1897. Both at school and at college he took high honors; at Sheffield especially in chemistry and for general excellence. He became chairman of the executive board of the *Yale Scientific Monthly*, and was otherwise honored by his class and society associates. His first professional position was that of Manager of the Saratoga mine at Central City, Colo. He was next Assistant Geologist of the Colorado Fuel & Iron Co., for which he examined and reported on coal and iron properties in several counties. He then accepted the superintendency of the Fiero, N. M., copper-mines of the Gilchrist & Dawson Co., and, while under this engagement, was attacked by typhoid fever, narrowly escaping death. In 1901 he became Treasurer and General Manager of the Northern Coal & Coke Co. of Denver, holding this position until the time of his decease. In the autumn of 1903 he was again attacked by typhoid fever, and never recovered. He was married in 1902. Mr. Best became a member of the Institute in 1889.

Luke W. Bryan, a leading colliery engineer and operator in the Southwest, died at Kansas City, Mo., March 26, 1905. He began his career as a boy picking slate at the Pink Ash breaker, Jeddo, Pa., 1862–4. From 1870, for five years he worked in various capacities in the anthracite mines of Pennsylvania. In 1875 he engaged in opening and operating the Spadro-Outi and Coal-Hill mines on the Missouri Pacific Railway, and remained in that work until 1886, when he was made Superintendent for the Kansas & Texas Coal Company of St. Louis, Mo. He held that position until 1894, when he became United States Mine Inspector for the Indian Territory. He filled many important positions from that time on, having been Industrial Agent for the Missouri, Kansas & Texas Railway;

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* Information concerning Mr. Best's life was not received in time to include the notice in the 1905 *Bulletin*, although his death was included in the list.

General Manager of the Mexican Gulf Coal & Transportation Co., operating coke-ovens at Aldersen, and mines and coke-ovens at Howe, both in the Choctaw Nation. He was Vice-President of the State National Bank of South McAlester, I. T., where he made his residence; President of the Bryan Coal & Lumber Co.; and largely interested in the Degnan-McConnell Coal Co. He joined the Institute in 1901.

Edwin Stout Daugherty was born in Dubuque, Iowa, January 13, 1874. From 1892, for two years he was employed as draughtsman in the U. S. Navy Department, in connection with the construction of the torpedo-boat *Ericsson* and the revenue cutter *William Windom.* From 1894 to 1897 he was draughtsman and engineer in the construction department of the Denver & Rio Grande R.R. Co. During the next following two years he was Engineer for the Pueblo (Colo.) Smelting & Refining Co., the Portland Gold Mining Co. at Victor, Colo., and at the iron-mines of the Colorado Fuel & Iron Co. After this, he went to South America as Engineer for the Inca Mining Co. and the Inca Rubber Co., Tirapota, Peru. In August, 1905, he was attacked by illness, and on September 3d got up from his sick bed and wandered away from his headquarters into the surrounding forest, where his body was found seventeen days later. He probably died from hemorrhage of the brain. He had been a member of the Institute for less than a year.

William Scott de Camp, born in 1846 at Powerville, N. J., died at his residence in Mount Morris Park West, N. Y., on April 8, 1905. As a civil and mining engineer, he had become interested in forest lands, parks, timber, and mines in the Adirondack regions of Herkimer county, N. Y., and had personally, as an expert forester, the care of some 40,000 acres of forest land there. He was also interested in Morris county mines, in New Jersey. A member of the Society of American Engineers, the American Forestry Association, and the Adirondack League Club, he had been a member of this Institute since 1875. He had but recently returned from a trip to the Bermudas, when he was stricken with pneumonia, and died after a very short illness. Mr. De Camp was a frequent and congenial attendant upon the meetings and participant in the excursions of this Institute for many years, and his death is deplored by innumerable friends among its members.

John Broome Guinn, Jr., born at Webb City, Mo., about 1872, died in St. Louis on May 5, 1905. He studied at the Washington University, St. Louis, and for his engineering course at Cornell University, N. Y. In 1895 he was engaged in mining at Cripple Creek and in the San Juan country near Silverton, Colo., and in 1896 became Superintendent of the Los Angeles Gold Mining Co., Cripple Creek, under the management of Arthur Winslow. From 1897 to 1902 he was Superintendent of the upper workings and tram, power-house and sawmill of the Durant Mining Co. and associated companies at Aspen, Colo., under the management of Francis T. Freeland. In 1902 he was Manager of the Guinn Mining Co. and other properties at Joplin, Mo., in which he and several of his relatives were interested—a large affair, covering several thousand acres of lead and zinc lands, with six or seven concentrating mills in operation. These properties were taken over by the Joplin Consolidated Mining Co., of which Mr. Guinn was President and General Manager until his death. In 1905 he removed to St. Louis, making frequent visits to Joplin. Mr. Guinn was a competent engineer, faithful and honorable in his dealings, of engaging manner and friendly, hospitable disposition. He was a member of the Elk Lodge at Joplin, and joined this Institute in 1897.

Dana C. Irish, born July 17, 1865, at Palermo, N. Y., was killed April 4, 1905, by falling from a broken plank at the Santo Niño mine, Tapona, Durango, Mexico. His technical studies were at the State School of Mines, Golden City, Colo., 1888–9, and in 1890–1 he was foreman at the Lamartine mine at Idaho Springs. In 1891–2 he went to the State of Chihuahua, Mex., and in 1893 was Superintendent of the Belen mine and concentrator at La Barranca, Sonora. In 1894–5 he was again at the Lamartine mine, and in 1896–7 was Assayer at Brodie's mill, Cripple Creek, Colo. For several years he followed the specialty of chemist, and in 1897–8 returned to Mexico, where he had charge of cyanide plants. In 1899 he became Chemist and Assistant Metallurgist for the Compañia Minera de Peñoles, at Mapimi, Durango, Mex., and, later, Superintendent of the mining properties of the Compañia Minera Koehler & Wahrmund, Valardeña, Durango, in whose employ he met his death. Mr. Irish joined the Institute in 1900. He was a man of excellent practical judgment, considerate in manner, and highly esteemed by his associates.

Harry Hugh Lee, born in Independence, Mo., about forty years ago, removed with his parents to Denver, Colo., when a mere child, his father, W. D. Lee, being interested in mining and real estate. Except for two years of the family's residence in Leadville, young Lee spent his early life in Denver, being educated at the public grammar and high school, and then becoming a student at the Western Reserve College in Ohio. On the death of his father he returned to Denver (1884), and in 1885 was appointed a Clerk in the Denver Post Office, where he remained three years, all his leisure time having been spent in studying law. He was admitted to the bar in 1888, and, in company with W. H. Bryant, entered the law office of Patterson & Thomas. The dissolution of this firm in 1889 was followed in 1890 by the formation of a new one—Thomas, Bryant & Lee, which continued until Mr. Lee's sudden death, from acute kidney trouble, on April 21, 1905.

Mr. Lee was one of the best known lawyers of Denver, having taken active part in many important cases. He was especially interested in mining and mining law, and became an associate member of this Institute in 1899. He was a man well read, of clear mind, of facile and cogent speech. Socially, he was a great favorite, and, although holding no office, was prominent in politics. He was a member of all the principal clubs of Denver and of Colorado Springs, and his death—as that of a brilliant man in full career, whose friends looked to him with confidence for further achievements—brought a shock to a wide circle of interests in Colorado.

William Alford Lindsay, born in Santiago de Chile, October 21, 1861, died in Monterey, Mexico, January 26, 1905. He was a graduate ef the Collegiate College, Victoria, B. C., in 1877, and for a year thereafter served as rodman and instrument-man in the Canadian Pacific railway surveys. From 1878 to 1890 he was, first, Assistant, and, later, Chief Engineer of the Wellington and Union Coal Companies, B. C.; 1890–01, in general practice as mining engineer in Denver, Colo.; 1891–3, Resident Engineer of the Choctaw, Oklahoma & Gulf, and the Kansas City, Pittsburgh & Gulf railways; 1893–9, engaged upon mineral, forestry, and general scientific investigation for the U. S. Geological Survey in Indian Territory, Montana, and Arizona—the last work he did for the government being to run the 98th meridian line. In 1900–01 he engaged in engineering work in the mines of the Choctaw, Oklahoma & Gulf R. R. in Indian Territory. During 1901 he went to Mexico as Chief Engineer of the Mexican Coal & Coke Co., Las Esperanzas, Coahuila, superintending the construction work for their coal-mines. In 1903 he resigned this to take position as Coal Expert for the Compañia Fundidora de Fierro y Agero, of Monterey, developing their properties near Muzquiz, and opening up their San Felipe mines, all in Coahuila. This position he resigned in 1904 to exploit some coal lands in the vicinity of Sabinas, which he had purchased in connection with other parties (Messrs. Garcia Galan and Orturo Longego), and concerning which he was very enthusiastic. He was taken ill, and after a decline of about two months passed away. Mr. Lindsay was a man of marked kindness and generosity, and a general favorite among his associates, as well as highly esteemed for his efficiency, especially in coal mining. His Institute membership began in 1902.

Roland C. Luther, a widely known mining engineer, died on March 6, 1905, at Pottsville, Pa., in the fifty-ninth year of his age. In his early days of professional labor he held various positions under the Philadelphia & Reading Coal & Iron Co., and in 1875 went to Colorado, where, until 1882, he was engaged in engineering work in the silver-mines. In that year he returned to Pennsylvania and became the Chief Mining Engineer for the Reading Company, of which he was made General Superintendent in 1888. His masterly management of the Reading collieries and men, during the great anthracite strike of 1901–2, resulted in his becoming Vice-President of the company. After the decision of the Anthracite Coal Commission was rendered, Mr. Luther was one of the three men chosen by the companies to represent the operators on the Board of Conciliation, created to settle disputes arising over interpretations of the awards of the Commission. He became a member of the Institute in 1884.

James MacNaughton, born in Albany, N. Y., January 6, 1851, died of pneumonia in New York City, December 29, 1905. He graduated at Yale College (class of 1871). A geological exploration in the far West, chemical training at the Albany Medical College, two years at the Rensselaer Polytechnic, and later studies at the École des Ponts el Chaussées, Paris, with practical experience during 1875–9 in surveys for new reservoirs in Putnam county, N. Y., for the Croton Acqueduct Bureau, and as an engineer in construction work of the West Shore railroad along the Hudson river, gave him fine professional equipment. When Canada sent H. M. S. *The Alert* for exploration in the Hudson Bay country, he accompanied the expedition as an engineer. Later he identified himself with the MacIntyre Iron Co., being its President until his decease, and was also President of the Ferro-Titanium Co., with works at Niagara.

Mr. MacNaughton was a member of the Fort Orange and Country Clubs in Albany; a Vice-President of the Association for the Preservation of the Adirondacks; and, in New York, a member of the University, Arts, and Downtown Clubs, as well as of the American Society of Civil Engineers (1880) and of this Institute, which latter he joined in 1890.

Gordon McLean, who died June 6, 1905, at his residence, in Los Angeles, Cal., was born at Stillwater, N. S., in 1862. His father's connection with gold-mining in that province led him to adopt that profession. In 1879 he went to Colorado and New Mexico as a miner, and in 1882 to Morenci, Ariz., where he rose to be, in 1883, at the age of 21, Superintendent of the mines of the Detroit Copper Co. For twenty years he managed this property, acquiring and operating new mines, until at his retirement, in 1902, the number was about 100. When Phelps, Dodge & Co. bought out the other owners in 1897, Mr. McLean was retained as Mine Manager. As President of the Morenci Water Co. and the Morenci Improvement Co., he greatly promoted the welfare of the town. In March, 1902, to the sincere regret of the directors and employees of the Copper Co., he retired from his position as Mine-Manager, and removed to Los Angeles, where he died. He had been since 1899 a member of the Institute.

Herbert Holmes McNamara was born in Ishpeming, Mich., April 1, 1872. His training consisted of two years (1890—2) at the University of Minnesota, a year of practical field-work exploring in Ontario gold-fields with J. C. Foley (1894), and a year of laboratory work and study under C. H. Graham, M.E. (1895). From 1896 to 1898 he was in the North Carolina gold-fields; in 1898–9 working in the gold and copper camps about Prescott, Arizona; for several years engaged in exploration work in the Mogollan and Matitzal mountains and Crook Canyon of New Mexico, and in the iron regions of Minnesota. In 1902 he became the field-representative of the Dividend Development Co. of Chicago, and at the end of 1903 he went to Duluth, Minn., where he died, January 8, 1905. His membership in the Institute dated from 1902.

August R. Meyer, who died at his home in Kansas City, Mo., on December 1, 1905, was widely known as a metallurgist, especially in the silver-lead and the zinc smelting industries,—in the former from its earliest days and in the latter more recently. Mr. Meyer was trained in the Royal School of Mines at Freiberg, Saxony, and not long after Leadville, Colorado, became known for its silver-lead properties, he went thither and interested himself in ore-buying. He went into the smelting business with the Harrison Reduction Works, and later with the Arkansas Valley Smelting Co., which he came to control. When the Consolidated Kansas City Smelting and Refining Co. took over the Arkansas Valley Co., Mr. Meyer removed to Kansas City, and still later became a director and member of the operating committee of the American Smelting and Refining Co.,—which included the Kansas City works among its purchases. In 1901 he organized the South Western Chemical Co., for the manufacture of sulphuric acid and other chemicals, in Kansas City. A consolidation of this company with the Standard Acid Co. (engaged in smelting zinc-ore and making sulphuric acid at Iola, Kan.) was named the United Zinc and Chemical Co. Of this corporation Mr. Meyer was the President until his decease.

Mr. Meyer combined unusual business capacity with thorough scientific equipment as a metallurgist, and achieved a handsome success both in pecuniary returns and in professional recognition of his abilities. He contributed some valuable papers to Raymond's reports as U. S. Commissioner of Mining Statistics in early days; but, after becoming immersed in the conduct of his own scientific and commercial interests, he had but little time for writing.

Mr. Meyer took an active interest in the improvement of Kansas City, where he built a beautiful residence, in the style of a chateau, and inspired and promoted the municipal movement for a very extensive and picturesque park, and for the æsthetic treatment of the bluff along the Missouri riverfront.

He became a member of the Institute in 1886, and to many of its members, as to all his employees and business associates, he was a valued friend.

William Orr was born at Aitkenhead, Beith, Ayrshire, Scotland, September 1, 1870, and died in Denver, Colo., November 21, 1905. After schooling at Beith Academy, at about the age of sixteen he entered the employment of a dispensing chemist in Glasgow, where he remained three years, meantime, during the winters, attending evening classes and lectures. Assisted by receiving a "bursary" (scholarship), he now entered the Glasgow and West of Scotland Technical College, and in 1892 received its professional degree. He then joined the technical staff of the Cassel Gold Co. as research chemist and assayer, remaining in that employ until May, 1894, when he came to the United States in the same capacity for the Denver operating office of the Glasgow concern, the Gold and Silver Extraction Co. of America, Ltd. Here he remained until the time of his death, becoming Chief Chemist in 1904, and General Manager in 1905. Mr. Orr was reputed as a thoroughly well informed metallurgist, perfectly trustworthy, an agreeable associate, and a successful worker in his profession. He became a member of the Institute in 1897.

William J. Parker, Jr., was born February 21, 1878, at Cleveland, O., and graduated in 1898 from the Case School of Applied Science in that city. He went immediately to Mexico, and afterwards to several of the Western mining States, where he was employed in erecting cyanide-plants. Finally, he was engaged by the Whitney Reduction Co., of Salisbury, N. C., with which he remained until his sudden and early death. For six years he had charge of the assay-office and reduction-works, and the mining of the company at Gold Hill, N. C. He also surveyed the company's land, inaugurated hydraulic operations on the Yadkin river, and erected an electric light plant. Mr. E. B. C. Hambley, Vice-President of the Whitney Co., writes.—"He was a great student and a hard worker; he was honest, straightforward and thoroughly reliable, a first-class assayer and metallurgist. He was fearless and persistent, thoroughly competent in every particular, and had the fullest confidence of myself and the company." This promising life was cut short July 21, 1905, near Whitney, N. C., as Mr. Parker was riding near the works erecting under his supervision. A stroke of lightning killed him and his horse; several of the workmen were stunned, but not fatally injured. Mr. Parker joined the Institute in 1898.

Joseph Philips, Jr., died suddenly, of heart-failure, at Salem, Ky., October 13, 1905. He was born near Nashville, Tenn., January 16, 1873. His early education was received in the Preparatory School of the University of the South, Sewanee, Tenn., and his technical training at the School of Mines and Metallurgy, Lehigh University, where he graduated in 1896. He entered first the service of the Costa Rican government as mining engineer and metallurgist, returning to the United States in 1897. For the following three years he was with the Consolidated Gold, Mining & Milling Co., of Dahlonega, Ga., and after that went to Oaxaca, Mexico, as Manager and Mining Engineer of the Conejo, Colorado, Monterey, and Estrella gold-mines. At the time of his death he was engaged in development-work on zinc, lead, and fluorspar properties, near Salem, Ky. Mr. Philips became an associate of the Institute while yet a student, in 1895, and soon afterwards a member.

Charles O. Ripley was born in Nichols, N. Y., in 1833 and died September 21, 1905. He was a member of the firm of D. Ripley & Sons, of Newark, N. J., dealers in lumber and timber, and became interested in mining matters from his ownership of iron mining property. He was elected an associate of the Institute in 1902.

Emmerich J. Schmitz, born at Coblentz, Prussia, March 14, 1851, and a graduate of the Polytechnic Institute of Aachen, Prussia, who had been active in mining and engineering affairs in this country since 1879, died in New York City, April 5, 1905. His first engagement here was with the Thomas Iron Co. of Pennsylvania, and his observations during that period were published in an article entitled, "Upon the Present Stand of the Blast-Furnace Industries of the United States of America," in the *Berg-und Hütten-Männische Zeitung*, April 20, 1880. He was then employed by railroad interests in Tennessee to examine and report upon routes and mineral resources in Tennessee, Kentucky, and West Virginia, preliminarily to the construction of roads; and as geologist of the Louisville & Nashville R. R. Co. examined their lands in the Southern States. Some results of this work were published in the *Transactions* of this Institute in 1883, Mr. Schmitz having become a member in that year. A list of his several contributions appears below. During more than twenty years the examinations of Mr. Schmitz ranged from Canada and Nova Scotia over a dozen or more States of the Union to Mexico, Central America and Cuba, and at one time to the Philippines; and the objects of his examination were variously gold, silver, lead, zinc, coal, iron, furnaces, petroleum, asphalt, copper, cobalt, nickel, sulphur, talc, abestos, onyx, mineral waters, the value of street railways, comparison of electricity and steam as railway power, timber, general estimates, etc., as to all of which he made multitudinous reports. He was at one time in charge of the construction of the capitol buildings in Columbia, S. C.

His contributions to the *Transactions* were as follows:—

Title.	Volume.	Page.
Contributions to the Geology of Alabama, .	xiii.	144.

Title.	Volume.	Page.
Geology and Mineral Resources of the Rio Grande Region in Texas and Mexico, .	xii.	388.
The Wolf Benzine Burning Safety Lamp, .	xiv.	410.
The Structure of the Richmond Coal Basin, .	xxiv.	397.
A Section of Rich Patch Mountain at Iron Gate, Va., ...	xxv.	477.
Copper Ores in the Permian of Texas, . .	xxvi.	97.
Discussion, ...	xxvi.	1051.
Notes of a Reconnaissance from Springfield, Mo., into Arkansas, ...	xxviii.	264.

Ludwig Philip Seeger, born and educated in Frankfort-on-Main, Germany, died in New York on the 10th of March, 1905, at the age of 31. He came to this country about 1892, and, as a trusted employee of the American Metal Co. and the Metallgesellschaft of Frankfort, became unusually well informed in all matters of the metal market. He was an earnest Free Mason, and State Secretary of the German Lodge here. His genial nature gave him many friends. He became an associate member of the Institute in 1900.

Jacob Johnston Sperry, of whose death the Institute was apprised late in 1905, as having occurred December 26, 1902, was born in Amsterdam, Va., August 1, 1861. He studied at the Virginia Agricultural and Mining College, Blacksburg (now Virginia Polytechnic Institute). In 1880–1 he worked for the Norfolk & Western Railroad on their civil engineering corps, and in 1881–2 on the Georgia Pacific. From 1882 to 1885 he was prospecting in Colorado; 1885 to 1893 was spent in the employ of the Northern and Western R.R.; from 1890 at Hemphill, W. Va., as resident engineer of that portion of the road. Between 1893 and 1900 Mr. Sperry was coal-prospecting in Western Virginia, especially investigating the conditions of the deposits in the Tug river field, where he located and became owner of some 10,000 acres of coal lands. The "Sperry Vein" in McDowell county proved to be valuable; it was worked by the Sperry Coal & Coke Co. Mr. Sperry's death occurred at his home in Hemphill. His Institute membership began in 1900.

Gustavus H. Stoiber, President of the Iowa Gold Mining & Milling Co., who was born in New York City, December 26, 1857, died suddenly in Silverton, Colorado, August 1, 1905. He was educated in the public schools of New York, prepared for a business career in a commercial college, was engaged in business in New York and Philadelphia, and identified with various business and mining enterprises in and near Silverton, Colorado, since 1883. He became a member of the Institute in 1902.

William L. Study, who died June 8, 1905, was born in Tyrone, Pa., May 15, 1878. In 1897-98 he was employed as a practical miner with the Cibolo Creek Mill & Mining Co. (silver), of Shafter, Texas. In 1900, shortly after the discovery of the quicksilver deposits in Brewster county, of that State, he entered the employment of the Marfa & Mariposa Mining Co., of Terlingua, becoming Superintendent in 1902. That position he held until 1904, when, being interested in the development of the Big Bend Cinnabar Mining Co., he resigned from the Mariposa to become the Vice-President and Manager of the latter company, which position he held until the time of his death. Mr. Study had no technical education, but through books and close attention to the practical side of mining and furnace work, busying himself with the problems of economic mining, he became exceedingly proficient, especially in the development of the quicksilver industry. Of great quietness and steadiness of character, excellent ability, and thorough integrity, he stood exceptionally high in the estimation of his associates and of the important district where he was known. He became a member of the Institute early in 1905.

Robert Macnair Wilson Swan died at Pahang in the Malaysian Peninsula in January, 1905. He was born February 8, 1858, at Maryhill, near Glasgow, Scotland, and, without regular technical education, began work in May, 1876, sampling and assaying ores in various parts of Spain for D. Swan & Co., at which he continued until February, 1878. From September, 1878, to February, 1885, he was engaged in managing Calamine mines in the Island of Antiparos, Greece, for the same concern. From April, 1893, to May, 1894, he was examining

mining properties in Mashonaland for the Magar Syndicate. May, 1894, to September, 1896, found him Manager of the Glasgow Mashonaland Syndicate and the Northern Gold Fields of Mashonaland; and from September, 1896, to May, 1897, Manager of the Glasgow Explorers' Syndicate in Western Australia. During parts of 1897–98 he was reporting on mines in Siam for the Areacan Co., of London, and in 1900, when he joined this Institute, he was Manager of the Malaysian Co., of Bombay, engaged in directing operations at their mine on the Tui, in Pahang, and in exploring mines for them elsewhere in Malaysia and Siam. He was still in the management of this company's practical affairs at the time of his decease.

Mr. Swan, besides his connection with the Institute, which began in 1900, was a member of the Chemical Society, the Geological Society, and the Royal Geographical Society, all of London.

Richard Henry Terhune died in Easton, Pa., January 15, 1905. He came from Hackensack, N. J., in his early manhood, after a public school education, to take employment in the Novelty Iron Works of New York City. A simple mechanic, he had a taste for study and a desire to improve, intellectually and socially; so that he frugally saved his earnings until he could afford the time and the money for a technical training. He entered the Columbia School of Mines, and took his degree of E. M. in 1870, winning the appreciation of his fellows by his sterling qualities of character. One of them records an amusing instance of Terhune's correcting a professor's lecture on the steam-engine, both teacher and class being interested in his practical knowledge of the facts, as an observant mechanic, and pleased with his unassuming and respectful earnestness. These qualities—thoroughness of knowledge and simple sincerity—seem to have marked Mr. Terhune's course through life. After graduation in 1870 he became assistant to the late J. W. Foster in examination of Indiana coal fields; in 1871 he was with the Griswold Steel works; 1872-77 with the Joliet Steel Works; 1877-80 Assistant Superintendent and Superintendent of smelting-works in Utah; 1880-93, General Superintendent of the Hanauer Smelting Works, Utah; 1894, examining and reporting on mines and works; 1896, Chief

Engineer and Superintendent again of the Hanauer Works, and from 1900 to the end of his life, engaged in private practice as mining expert and consulting metallurgist, and 1901-1903 he was Managing Trustee and Superintendent of the Tomichi Valley Smelting Co., Sargent, Colo. Early in 1904 he removed from Denver to Easton, Pa., where in a little less than a year he closed a useful life.

Mr. Terhune joined the Institute originally in 1871, and resigned in 1873. He was again elected in 1886 and remained a member until his death.

His contributions to the *Transactions* were as follows:

Title.	Volume.	Page.
Malleable Cast-Iron, ...	i.	233.
Address of Welcome at Utah Meeting, . .	xvi.	
Ore- and Matte-Roasting in Utah, . . .	xvi.	18.
Notes on Cast-Steel Water-Jackets, . . .	xvii.	131.

Joseph Thiry was born in the Grand Duchy of Luxemburg, and after a good education and a life of varied experiences as engineer and metallurgist, both in Europe and America, died September 8, 1905, at Vesinet near Paris, France, in his 39th year. Mr. Thiry was connected with wealthy iron-manufacturers in Luxemburg, which gave him his early bent; but he came to America in 1891, while still young, and was for some time employed in the metallurgical laboratory of Ricketts & Banks, mining engineers, in New York City. In 1893 he was with the Sterling Iron & Railway Co., of Sterlington, N. Y., and after a year or so again with Ricketts & Banks. In 1896 we find him in Brebach, Saarbrucken, Germany, Manager of blast furnace and coke oven plant of the Stumm Works; in 1901, in London, England; 1903 at Inch-Cape, Chiselhurst, England, as Manager for the Otto-Hilgenstock Coke-Oven Co., Limited, of London; and in 1904 he settled in Paris, as Director of the Paris bureau of Messrs. Dr. C. Otto & Co., while also carrying on his own office as *Ingénieur*. Mr. Thiry's associates in America retain very agreeable memories of him. He joined the Institute in 1892, while in New York, and maintained the connection until his decease.

John N. Tisdale was born in Simcoe, Ontario, Canada, in 1845, and met his death by drowning in the Harlem river, New York City, in November, 1905. He was not a technically educated engineer, but gained knowledge by practical experience in prospecting and in the equipment, development and management of mining properties. For some years of his active career he was engaged upon a large scale in the cattle business in Wyoming and Utah, with headquarters in Salt Lake City, where he was well known. During the 90's he went to Alaska, looking for property to develop for himself and others. He spent some money and time developing prospects near Sitka and Juneau, and acquired some interests near Wrangell; but the permanent location of his activity was at Snettisham. Here the Sitka-Alaska Gold Mining Co., which he represented and in which he was heavily interested, in 1899 purchased the property, became the Alaska-Snettisham Gold Mining Co., erected a wharf on the bay, a stamp mill and other improvements, and operated the mines. Mr. Tisdale was President and Manager until his death. The Vice-President was Mr. W. A. Shaw, of the Calumet & Hecla Mining Co., of Boston, Mass. Mr. Tisdale was a man of marked personality, having many friends in Alaska and strong financial backing in the East. He was buoyant and generous, hopeful in disposition, and full of energy and activity. He became prominent in Alaska politics, and at one time was urgently recommended for appointment as territorial governer. He joined the Institute in 1903.

Alfred Isham Totten was born in Hartford, Conn., son of the Rev. Silas Totten, D.D., at that time President of Trinity College. Later, Dr. Totten presided over William and Mary College in Virginia, in which State the son passed much of his boyhood until he was eighteen years of age, when the family removed to Lexington, Ky. Here he attended Kentucky University. When the City of Cincinnati undertook to build the Southern Railway, in 1869, he joined one of the preliminary surveying parties, and after a valuable field experience of three years, was placed in charge of the office in Cincinnati, where he remained two years. In 1874, when the work of construction began, Mr. Totten was assigned to field work, and completed over thirty miles of the road. After eight years in the employ of the Cincinnati Southern R. R., he opened an office for general business in Lexington, Ky., while holding the position of City Engineer. Later, he entered the field of mining, and developed the Barren Fork Coal Mine in the Cumberland Mountains on the line of his old road, and was for a number of years their engineer and manager. This was admitted to be the best planned coal mine of that region, and under Mr. Totten's wise and just management was undisturbed by strikes. In 1886 Mr. Totten was made Supervisor of Streets in Lexington; many improvements now making in that city were suggested and advocated by him twenty years ago. He built, as engineer, the Lexington Passenger and Belt Railway and an electric light and power plant. After this he became manager of Glen Mary Mines in Tennessee, conducting them successfully for some years, and resigning to forward an enterprise in gold mining in Northeastern Georgia. This venture proving a failure, he engaged in mining operations in Kentucky and West Virginia; and, in Pennsylvania, built the Pittsburg, McKeesport and Connellsville Electric Railway, seventy-five miles in length.

On January 1, 1905, Mr. Totten went to Tracy City, Tennessee, to take charge of work for the Tennessee Coal and Iron Co. There he died, on July 28 of the same year, to the sorrow of all who knew him. He possessed in an eminent degree the affection and trust of all his friends, and especially of those in all walks of life who worked with him, while his orderly and systematic qualities of mind, excellent judgment and varied experience made him a valuable member of his profession. He joined the Institute in 1897.

Walter Harry Virgoe was born in England, December 2, 1868. He was educated at King's College, London (Engineering Department). Owing to feeble health, in 1891 he sought out-door life in America, and in 1892 became chemist to the Gold and Silver Extraction Co. of America, Ltd., in Denver; from 1894 to 1898 he filled the same position with the American Gold and Silver Recovery Co., Ltd., Mexico City. Still seeking relief from asthma, which was his life-long foe, and the cause of his death at last, he went to South Africa, and in 1899–1900 he was Cyanide Superintendent to Regende, Ltd., Rhodesia. In May, 1900, he returned to Mexico City as Chief Chemist for the Mexican Gold and Silver Recovery Co., Ltd., again, and while in their service designed several cyanide plants, which were erected. In 1903 he returned to London for some months, but in 1904 was again in Mexico City, where he died May 18, 1905. His Institute membership dated from 1902.

Charles H. Wellman died June 22, 1905, from injuries received in the wreck of the "Twentieth Century Limited" railway train at Mentor, O., the day previous. He was born in Nashua, N. H., June 12, 1865, his father being at that time Superintendent of the Nashua Iron Co., and his early years familiarizing him with the processes of iron-making. In October, 1881, he was taken into the employ of the Morgan Engineering Co., of Alliance, O., where he served his time as machinist and draughtsman. In 1885 he joined the Otis Steel Works, of Cleveland, O., as chief draughtsman, and was soon put in charge of the open-hearth department. After five years he became, in 1890, Superintendent of the Wellman Steel Co. in Thurlow, Pa., and in 1895 Superintendent of the open-hearth department of the Illinois Steel Co. at South Chicago. In 1896 he organized, with John W. Seaver, the Wellman-Seaver Engineering Co., which in 1902, recognizing the services of Thomas R. Morgan, manager of the works, was renamed the Wellman-Seaver-Morgan Engineering Co., and in 1903, following its absorption of the Webster-Camp & Lane Co., of Alliance, O., it became the Wellman-Seaver-Morgan Co. The railway disaster deprived this company of two of its most efficient workers, Mr. Morgan being killed instantly and Mr. Wellman dying the next day. Mr. Wellman was recognized as one of the foremost steel engineers of the country, being an inventor as well as a producer. At the time of his death he was also President of the Electric Controller and Supply Co. He joined the Institute in 1890.

Harvey Ladew Williams was born in New York City, March 31, 1875, and died August 4, 1905. Mr. Williams was a graduate of Harvard, Class of 1897. He spent most of the years 1900 and 1901 in the study of mineralogy, chemistry and mining under the direction of his father, Mr. John T. Williams (a graduate of the Columbia School of Mines and a member of the Institute), and spent about six months in 1902–3 in examining mining properties in Arizona. Since March, 1903, he had been in charge of the mining department (including active supervision of mining in various clay- and vein-deposits of barytes) of the Bristol (Tenn.) Barium Works, owned by John T. Williams & Sons, of New York City and Bristol, of which firm he then became a member. He was also active in the investigation of other mining properties in North Carolina, Tennessee and Virginia, his firm having interests in the Blue Ridge Mineral & Lumber Co., the Bristol Barrel & Stave Mills, and other properties. Mr. Williams was elected an Associate of the Institute in September, 1903, and in February, 1904, was made a Member.

SUBJECT TO REVISION.

[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

A Novel Method of Mining Kaolin.

BY ALBERT R. LEDOUX, NEW YORK, N. Y.

(Bethlehem Meeting, February, 1906.)

I AM indebted to The Kaolin Co. of West Cornwall, Conn., and particularly to its engineer, Mr. M. Wanner, for permission to make public, through the *Transactions* of the American Institute of Mining Engineers, the interesting results of his experiments, having in view the winning of kaolin from deep deposits without shaft-sinking or removing of the overburden. So far as I am aware, nothing like it has been accomplished heretofore, although it reminds one of the methods successfully employed in Louisiana for the winning of sulphur from deep beds by the sinking of pipes one within another, injecting superheated steam under pressure through one pipe, the heat of the steam liquefying the sulphur and the pressure forcing it up through the other pipe to bins at the surface.

The kaolin-deposit at West Cornwall is an alteration *in situ*—that is, it is not sedimentary. A series of clay-veins dipping about 50° from the vertical, lie between a foot-wall of limonite and a hanging-wall of gneiss and hornblende schist. The clay-veins alternate with veins or seams of more or less broken quartz, and unaltered feldspar. The deposit, which occurs at a point about 600 ft. above the Housatonic river, was opened five years ago, and about 5,000 tons of a superior grade of washed kaolin has been extracted from open pits and sold. It soon became evident that this mode of extracting the product would prove unremunerative, by reason of the dip of the vein and the intercalary strata and lenses of quartz, and a more satisfactory method of working the deposit was sought. It is well understood, that, in the preparation of all clays for market, especially residuary kaolin, the most important as well as the most difficult step is the washing of the crude product. The difficulties increase with the percentage of foreign matter, especially quartz and mica, contained in the product, hence a system of working a clay-deposit by which it would be possible to obtain the crude material from great depths without removing the overburden (or, in the case of veins, without resorting to shafts, drifts and other underground workings requiring timbering), and, at the same time, minimize the raising of waste material with the marketable product, would be of great advantage.

Proceeding on the logic of these observations, Mr. Wanner, the engineer temporarily in charge of the operations at the mines, conceived the scheme to disintegrate the kaolin *in situ* by means of jets of water under sufficient pressure and floating the resultant product to the surface. This product is technically known in the pottery trade as "slip." To accomplish this result holes are drilled through the overlying gneiss, a pipe of 4-in. internal diameter is inserted into the bore and driven into the clay body to within a few feet of the foot-wall. The wells in operation are from 50 to 198 ft. deep. Into this 4-in. pipe or "casing," an interior pipe is inserted of 2-in. external diameter, leaving an annular space of 1-in. for the flow of the slip. The lower end of the internal pipe is provided with a mouthpiece with several nozzle-like openings for the exit of the water; the mouthpiece rests on the clay body, and the interior pipe sinks gradually as the clay is removed until it rests on the foot-wall of the vein. For the operation of these "hydraulics" a head of water equivalent to a pressure of from 40 to 60 lb. per sq. in. is required, according to the nature of the vein-matter.

Residuary kaolin slacks more or less readily, according to the amount of sand and mica mixed with it. In the case in point, it has been found that a pressure of 40 lb. is amply sufficent to cause the disintegration, the vein-matter contains 20 per cent. and the slip, discharged by the hydraulics, from 60 to 75 per cent. of pure kaolin. The purity of the discharged slip is inversely proportional to the velocity of the overflow.

Observations made during the past summer's work have shown that the overflow contains from 5 to 10 per cent. of solid matter. A discharge of 100 gal. per min. through the annular space of 9.42 sq. in. from a depth of 127 ft. yielded 5 per cent. of solid matter, of which 75 per cent. was pure kaolin, while a discharge of 200 gal. per min. through the same orifice from the same depth, gave a slip containing 10 per cent. of solid matter but only 54 per cent. of pure kaolin, the rest being finely-divided quartz and mica.

One of the factors directly responsible for the purity of the slip as well as for the facility of the separation or washing of the product is the accumulation of the waste material in the cavities caused by the withdrawal of the product through which the slip has to pass to arrive at the lower orifice of the casing. The passage of the slip through this mass, which consists principally of a breccia of quartz, acts as a scouring medium, effectively helps in the separation of the clay particles from associated fine scales of mica, and renders easy its final division by subsidence.

In addition to the lessening of the cost of extraction, the method described has effectually solved the transportation of the product to the railroad. Heretofore, the kaolin washed and dried at the mines was carted by teams over a difficult mountain road to West Cornwall, 4 miles distant. The fuel for the whole plant had to be hauled up the mountain the same distance. With slip issuing from the hydraulics of only 10 per cent. of solid matter and sufficient fineness to pass through 100-mesh screens, the conveyance of the product through a pipe-line to the Housatonic valley offers no difficulty, and the company now contemplates the erection of a new washing-plant adjacent to the river and railroad.

[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

Notes on the Gayley Dry-Air Blast-Process.

BY C. A. MEISSNER, NEW YORK.

(Bethlehem Meeting, February, 1906.)

THE following is a further discussion of the paper of James Gayley, "The Application of Dry-Air Blast to the Manufacture of Iron" (*Trans.*, xxxv., 746), with special reference to his supplementary paper (*Bi-Monthly Bulletin*, No. 4, July, 1905, pp. 797 to 819), and to the paper of J. E. Johnson, Jr., "Notes on the Physical Action of the Blast Furnace" (*Bi-Monthly Bulletin*, No. 5, September, 1905, pp. 1111 to 1146).

Mr. Gayley's paper has been discussed also by E. Windsor Richards, R. W. Raymond, E. H. Saniter, W. J. Foster, H. M. Howe, V. Pendred, B. H. Thwaite, James Gayley and Alexander Pourcel (*Trans.*, xxxv., pp. 1022 to 1042), Joseph W. Richards (*Bi-Monthly Bulletin*, No. 4, July, 1905, pp. 703 to 718); T. W. Robinson (*Bi-Monthly Bulletin*, No. 4, July, 1905, pp. 788 to 796); C. B. Dudley, R. W. Raymond, J. E. Johnson, Jr., W. F. Mattes, James Gayley, David Baker, John Birkinbine and F. E. Bachman (*Bi-Monthly Bulletin*, No. 5, September, 1905, pp. 1147 to 1152); E. de Mille Campbell (*Bi-Monthly Bulletin*, No. 1, January, 1906, pp. 25 to 50); John Birkinbine (*Bi-Monthly Bulletin*, No. 1, January, 1906, pp. 137, 138).

At the Washington meeting of the Institute, May, 1905, a very instructive and interesting paper was presented by Mr. J. E. Johnson, Jr., entitled "Notes on the Physical Action of the Blast Furnace,"[1] in which reference is made to Mr. Gayley's dry-blast process. A few of Mr. Johnson's conclusions, as summarized in the last pages of his paper, do not appear to me to be in complete accordance with the results obtained at the Isabella furnaces; and I therefore present the following notes, which may throw further light on this subject:

Mr. Gayley has called attention to the fact that the moisture in the air is an extremely variable and uncertain factor; and that, while every possible effort has been made to control the composition of the burden of raw materials within 10 per cent. of variation, yet there has been no such control of the composition of the blast, the actual weight of which is 1.43 to 1 of the weight of the solid charge, and which may vary daily from 20 to 100 per cent. in its content of moisture and in its temperature. Those who have studied the subject know that these conditions exist wherever iron is made. The gist of Mr Gayley's labors in this direction is the endeavor to secure a uniform composition of the air supply (which, after all, is the largest and most important factor in the manufacture of iron), as the furnaceman does for the mixture of fuel, ore or flux, constituting the solid charge.

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[1] Published in *Bi-Monthly Bulletin*, No. 5, September, 1905, pp. 1111 to 1146.

Various suggestions to bring about this result have been made by many writers; and, in some cases, it has been argued that the reported results of Mr. Gayley's dry-air blast, showing a gain of from 10 to 20 per cent. in the output of pig-iron, and a saving of from 10 to 20 per cent. in coke consumption, were due to natural air conditions existing at the time of his experiments. It has also been pointed out that these reported economies were obtained in the winter months.[2] This criticism, however plausible, was based on insufficient data; Mr. Gayley's first figures having covered, in fact, but a comparatively short period, and that largely in the winter months. But, according to later experience, covering summer months as well, all the dry-air blast periods indicate a similar tendency to continous higher pig-iron production and a lower coke consumption. This is shown by additional data given below.

A comparison of the natural-blast records of Furnace No. 3 for the winter months, February and March, 1903, with similar previous records, showed that the coke-consumption in these winter months (2,225 lb. per ton of pig-iron produced) did not differ materially from that of the summer months. In 1904, like results were obtained; the fuel consumption (2,297 lb. per ton of pig-iron produced) being practically constant throughout the year; in fact, the monthly records of both furnaces during the natural-air periods preceding the dry-blast periods showed as uniform and steady operations as is possible to get under such conditions. In 1895, however, the records show that the lowest coke-consumption, averaging about 1,800 lb. per ton of pig-iron produced, was obtained during the three winter months of the dry-air period of Furnace No. 3, showing that the gain from the use of dry-blast is by no means restricted to the summer months. In the winter months, given above, Furnace No. 3, running on mill-iron, saved at least 20 per cent. in coke-consumption, as compared with that required by natural air, under otherwise similar conditions in the winter months of the two preceding years.

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[2] *Bi-Monthly Bulletin*, No. 5, September, 1905, p. ——.

It has also been said that in very cold, dry periods, an increase in pig-iron production, and a decrease in coke-consumption, equal to those reported by Mr. Gayley, have been obtained. It is to be regretted that these statements were not accompanied with tabulated data, permitting critical comparisons. Such data should show the length of time covered, and, especially, whether the 20 per cent. increase of pig-iron production and the 20 per cent. decrease in coke-consumption were obtained simultaneously.

I have in mind here Mr. Walter Crooks' graphic statement[3] showing a gain in pig-iron production and a decrease in coke-consumption during winter months over summer months for two years; yet even these figures show but a 6 per cent. increase in pig-iron produced and 9 per cent. decrease in the quantity of coke consumed. No data are given showing the actual production of pig-iron, the consumption of coke or the temperature of the blast.

Among the records which I have been able to study (those of about 90 furnaces for from four to six years back), there are none which show that any such percentage of iron-increase and coke-decrease either took place simultaneously under natural dry atmospheric conditions, or even covered separately any long period. They often show a distinct tendency to an increase in the pig-iron production during such natural dry-air conditions; but with a few exceptions, practically stationary or but slightly varying coke-consumption. In the early part of November, 1905, when the atmospheric conditions gave an almost dry air, one of the Isabella furnaces, running with natural blast, increased its production from 375 to 430 tons per day; yet during all this time, the coke-consumption remained practically stationary, the increased iron-production being due to the temporary ability to blow harder, which meant an increase in the number of revolutions. Moreover, this lasted only eight or ten days; so that it presented no parallel to Mr. Gayley's results, which were obtained with a decreased number of revolutions and an immediate and simultaneous increase in the production of iron and a decrease in the coke-consumption.

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[3] Discussion, *Journal of the Iron and Steel Institute*, vol. lxvii., pp. 267, 268.

In short, the economies effected by the use of the dry-air blast are now shown to be uniform and continuous for periods of months together, and to be practically unaffected by stoppages, repairs, or other disturbances. These economies have been achieved with two furnaces that had run for more than two and three years, had produced respectively more than 300,000 and nearly 400,000 tons of pig-iron upon their existing linings, had been repeatedly banked, and were more or less damaged. I think this record cannot be matched from experience with natural-air blast, and is, therefore, conclusive as to the value of Mr. Gayley's invention.

Another point brought out by some of the arguments on the subject, and one which is apparently carrying great weight in many minds, is the one of the temperature of the blast.

It has been stated frequently that an increase in blast-temperature alone would accomplish the same results as those obtained by Mr. Gayley. The necessary increase of temperature to do this has been variously estimated at from 150° to 400° F., and the estimates of the amount of coke saved by every 100° of increased blast-temperature vary considerably.

Table I., giving the average blast-temperature during the natural-blast and dry-blast periods of the two furnaces named, shows a difference of average of temperature between the first natural-air period and the dry-blast period of Furnace No. 1, of about 50° F. only, while in the second natural-air period, following that of the dry-blast, the average blast-temperature was actually about 10° F. higher. For Furnace No. 3, the natural-air temperature was only 45° below that of the dry-blast.

According to Fig. 2 of Mr. Johnson's paper,[4] air at 800° F., containing 5 grains of moisture per cu. ft., would yield about 1,200 B.t.u., and air at 850° F., with 2 grains of moisture per cu. ft., would yield about 1,450 B.t.u. of "available heat" per lb. of fuel consumed. The latter figure fairly represents dry-blast conditions, and (assuming the average coke-consumption with natural-blast as 2,275 lb. per ton of pig-iron produced) indicates a coke-consumption, for dry-blast, of 1,875 lb., which closely accords with practice.

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[4] *Bi-Monthly Bulletin*, No. 5, September, 1905, p. 1132.

We may proceed to inquire what would be the effect of dry-blast combined with higher temperature—say, 1,200° F., which is 350° F. more than that of the blast at the Isabella furnaces during the dry-blast period in which the coke-consumption was reduced to 1,850 lb. According to Mr. Johnson's diagram, this increase from 850° F. to 1,200° F., on a blast containing 2 grains of moisture per cu. ft., should increase the "available heat" from 1,450 to about 1,850 B.t.u. Theoretically, this would reduce the coke-consumption of 1,875 lb. for the former temperature, to about 1,270 lb. for the latter. But, if we apply the practical factor of 50 lb. less coke per ton of pig-iron for every additional 100° F. of blast-temperature, we shall have, in the case stated, a saving of 175 lb. of coke per 350° F. of additional temperature; and consequently, for blast at 1,200° F. containing 2 grains of moisture per cu. ft., a coke-consumption of 1,700 lb. per ton of pig-iron produced. This appears to be a reasonable expectation, according to our present knowledge of the effects of the dry blast.

Further study of the monthly blast-temperatures showed that, in many cases, the monthly averages for natural air were higher than for dry-blast, and yet that neither coke-consumption nor product of iron differed materially in those particular months from the corresponding figures for other months of natural-air blast, characterized by 100° F. or 150° F. lower blast-temperature. In other words, the effects of the blast-temperature, within these limits, were counteracted by other causes, such as the varying atmospheric temperature and moisture. Furnace-men are obliged to carry a surplus of coke above the theoretical requirement, as a reserve source of heat to meet these frequently great and sudden changes in the atmosphere; and the existence of this reserve (which would not be required with dry blast) prevents not only the close regulation of tem-

TABLE I.—*Comparison of Natural Air and Dry-Blast*

Period.	No. of Days in Period.	Kind of Iron.	Av. Tons Pig Per Day.	Av. Coke Consumption per Ton Pig.	Temp. Degrees F.		Engine Rev. Per Min.	Grains of Moisture.			
								Atmosphere		Dry Blast.	
					Blast.	Gases		Day.	Night	Day.	Night
Furnace No. 1.											
First natural-air period......... From July to Oct. 15, 1903. (Banked three months). Jan. to Aug.. 1904.	314	Basic. Besse'r.	357	2,275	807	516	113	3.93	3.92	....	....
Dry-blast period................... From Aug. 1904, to Jan., 1905, and including Aug. 1905.	164	Basic. Besse'r.	436	1,821	854	397	96	3.50	3.56	1.33	1.24
Second natural-air period..... From Jan. to Aug., 1905.	205	Basic. Besse'r.	383	2,256	863	501	108	3.44	3.60	....	....
Furnace No. 3.											
First natural-air period......... From Jan. to Sept., 1903. Banked four months. Feb. to May, 1904. Banked three months. Sep. to Nov., 1904.	478	Basic. Besse'r.	370	2,258	775	....	108	3.22	3.35	....	....
Partial dry-blast period......... Natural air December, 1904 Dec., 1904, to Jan. 15, 1905.	21	Basic.	399	2,307	....	....	....	....	....	....	....
*One engine dry-blast, Dec.	10	Basic.	453	2.204	785	....	104	1.41	1.47	....	....
One engine dry-blast, Jan..	10	Basic.	409	2,329	....	....	....	....	....	....	....
Two engines dry-blast, Jan.	4	Basic.	425	1.980	680	....	111	1.46	1.46	....	....
Three engines dry-blast Jan..................................	17	Basic.	432	1.824	....	....	....	....	....	....	....
Dry-blast period...................... From Jan. to Aug., 1905.	208	Besse'r.	400	1.961	820	448	98	3.44	3.60	1.26	1.17

* Three engines on each furnace.

perature, engine-revolutions, etc., but also the clear interpretation of their effects. It has been suggested, indeed, that a continuous automatic record of these factors would permit a better control of them; but such frequent changes (sometimes from hour to hour) as this suggestion would require in the engine-revolutions, blast-temperature, charge, etc., would be not only well nigh impracticable, but might also cause other evils, incident to irregular running, and greater than those which they were intended to remedy.

The natural atmospheric irregularities mentioned unquestionably affect the zone of fusion in the furnace; and such changes in the position and condition of this zone, which are the chief causes of difficulty in furnace-management, are, at times, by reason of atmospheric changes outside, much greater than has been generally assumed. Obviously, the wisest course, if practicable, is not passively to suffer these effects to begin and then try to remedy them, but to prevent them altogether by securing uniform blast-conditions, so that the zone of fusion

Periods of Isabella Furnaces Nos. 1 *and* 3.

Temperature.				Ratio, Coke-Ore.	Tons of Ore Per Ton Pig.	Pounds Limestone Ton Pig.	Yield of Ore.			Charges Per Day.	Blast Pressure.	Flue-Dust Per Day, Tons.
Atmosphere		Dry Blast.										
Day.	Night	Day.	Night				Actual.	Theoretical.	Difference.			
52.4	59.1	....	....	1 to 1.96	1.96	1077	49.4	55.9	6.5	7.27	14.9	32.4
56.0	53.0	20.0	19.9	1 to 2.40	1.90	1052	52.9	54.9	2.0	78.0	14.1	18.9
49.1	55.3	....	....	1 to 1.89	1.91	965	51.1	56.8	5.2	83.0	13.9	21.0
50.1	50.0	....	....	1 to 1.90	1.90	1282	51.9	55.2	3.3	82.0	16.8	28.2
....	....	....	....	....	....	....	....	....	....	....	....	....
34.0	33.0	....	....	....	....	....	51.78	54.35	2.55	95.6	....	....
31.0	30.0	....	....	....	....	....	51.33	54.35	3.03	88.4	....	....
49.1	55.3	18.0	18.0	1 lo 2.11	1.85	1030	54.38	56.30	1.92	80.0 75.0	13.9	11.9

may be held steadily in its position; thereby preventing scaffolding and irregular running, increasing the life of the lining, and, above all, permitting a reduction of the amount of coke otherwise required as a margin of safety. It is not necessary to amplify this argument. The conditions involved are familiar to all furnace-men.

The temperature of the atmosphere, as supplied to the engine-cylinders, is a very important factor in the use of dry-air blast. The difference in weight of saturated and dry-air per cu. ft., at different temperatures, is shown in Table II.

TABLE II.—*Difference in Saturated and Dry-Air Per Cubic Foot at Different Temperatures.*

Grains of Moisture at 100 Per Cent. Saturation.	At	Saturated.	Dry.
0.55	0° F.	equals 0.0863 lb. per cu. ft. of air, or	0.0864
0.91	12° F.	equals 0.0841 lb. per cu. ft. of air, or	0.0842
2.12	32° F.	equals 0.0805 lb. per cu. ft. of air, or	0.0807
4.38	52° F.	equals 0.0772 lb. per cu. ft. of air, or	0.0776
8.54	72° F.	equals 0.0739 lb. per cu. ft. of air, or	0.0747
15.75	92° F.	equals 0.707 lb. per cu. ft. of air, or	0.0720

Table II. shows that a change of every 20° F. is equivalent to a change of 4 per cent. of the actual weight of the air pumped into the furnace per revolution, or every 5° F. is equivalent to 1 per cent. of the air by weight. Taking this on approximately 40,000 cu. ft. per minute blown at the Isabella works for one furnace, this 1 per cent. of difference in weight of air for every 5° would be equivalent to about 400 cu. ft. per minute, or a little more than the air blown in by one revolution. The effect of this can be shown in several ways. For instance, comparing Furnaces Nos. 1 and 3, the former running on dry-blast and the latter on natural air, both with the same air-cylinder capacity per min. (377 cu. ft. per rev.), we find that No. 1 ran 96 rev. or 36, 192 cu. ft. per min., or 51,840,000 cu. ft. per 24 h., dry-air blast entering at 28° (the weight of the air saturated at 2 grains of moisture, being 0.081 lb. per cu. ft.), and gave 4,199,040 lb. of air in 24 h.; while No. 3 ran 113 rev., or 42,600 cu. ft. per min., or 61,344,000 cu. ft. per 24 h., normal air entering at 90° (the weight of the air with 5 grains of moisture being 0.0711 lb. per cu. ft.) and gave 4,361,660 lb. of air in 24 hours.

In other words, about 3.75 per cent. less air goes in on 15 per cent. less blowing-requirement. As the temperature of the dry-air blast varies somewhat, and is usually lower, it can be accepted that practically the same amount of air enters by weight in the above stated conditions, thus materially reducing the power required.

To show more clearly the effect of uniformity of temperature, the data have been arranged in Tables III. and IV.

TABLE III.—*Some Results of the Dry-Blast Period of Furnace No. 1.*

1904.	Daily Pig Iron Make. Tons.	Coke-Consumption. Pounds.	Moisture in Dry Blast Grains.	Moisture in Air. Grains.	Temp. of Dry Blast. °F.	Temp. of Atmos. °F.
August, ...	448	1,753	1.80	5.62	27.1	71.0
September, . . .	442	1,754	1.56	5.15	22.0	71.5
October, ...	416	1,862	1.18	3.11	18.0	55.5
November, . . .	442	1,816	1.02	1.99	19.0	44.0
December, . . .	445	1,823	1.03	1.43	17.5	33.5
1905.						
January, ...	428	1,822	1.76	1.46	13.5	30.5
August, ...	411	1,829	1.70	5.94	23.0	75.0

This indicated that, *per se*, the moisture-content is not so controlling a factor as the temperature, or rather the uniformity of temperature. The differences in temperature in dry-air, though comparatively much less violent than those of moisture, are, of course, almost stationary compared to the differences in temperature of normal atmosphere as shown in the normal-blast period. As this matter appears of prime importance, I have arranged a similar statement of the dry-blast period of Furnace No. 3 in Table IV., in which the results appear of importance in showing that iron-production and coke-consumption are not entirely dependent on actual moisture-variations from month to month, in the dry-blast, or on even wider variations in the natural atmospheric air. They indicate, also, that the benefits secured are derived largely from the general uniformity in the moisture-content as well as the low degree of temperature of the air supplied to the blowing engines obtained through the use of dry-blast.

TABLE IV.—*Some Results of the Dry-Blast Period of Furnace No. 3.*

1905.	Daily Pig Iron Make. Tons.	Coke-Consumption. Pounds.	Moisture in Dry Blast Grains.	Moisture in Air. Grains.	Temp. of Dry Blast. °F.	Temp. of Atmos. °F.
February, ...	418	1,850	0.60	1.18	15.0	23.8
March, ...	407	1,837	0.95	2.26	14.0	43.8
April, ...	398	2,095	1.04	2.57	16.0	49.2
May, ...	436	2,024	1.50	4.08	23.0	62.2
June, ...	415	1,965	1.70	5.76	24.0	71.1

The actual lowering of both moisture and temperature is, of course, a very influential factor; but the variation of moisture within certain limits seems to be less important than the approximate uniformity in the weight of air going into the furnace,—the low temperature increasing the actual weight of air per revolution, or permitting the same amount of colder air by weight to be blown in by fewer revolutions.

Mr. R. A. Hadfield, in his recent Presidential address,[5] quoting an opinion that the economies ascribed to dry-blast "were conclusively shown to be due to increasing the burden of ore and the quantity of lime in the cinder, rather than to the use of dry-air," says:

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[5] *Journal of the Iron and Steel Institute*, vol. lxvii., No. 1 (1905), p. 58.

> "It is well known that, by increasing the burden of ore on a furnace, the temperature of the escaping gases is lowered, the quantity of fuel required to smelt a ton of ore is reduced, and the yield of the furnace is increased."

Since all well-managed furnaces using natural air carry already as much burden as they can, a further economy by means of a simple increase of burden is out of the question, unless it be made practicable by the use of the dry-blast. Whether the direct cause of such further economy is the increased burden, or any one of the other conditions discussed above, it is only through the dry-blast that the result is made possible. Unless it can be shown that the Isabella furnaces, when operated with natural blast, did not carry as heavy a burden or as much lime as they ought to have carried under the circumstances, this criticism falls to the ground.

If any one effect of the dry-blast is to be emphasized as the chief cause of the resultant economy, it is, as already remarked, the uniformity of the conditions secured combined with as low degree as possible—however they may be characterized. To secure this all-important uniformity, it is evident that care must be taken to preserve unchanged the temperature of the air between the cold air chamber and the engine cylinder. This should be secured by properly covering the pipes.

The following comparative statements and tables are offered in additional support and explanation of the views above set forth:

In order to emphasize further the effect of uniform and steady dry-blast, both as to moisture and temperature, reference should be made to the record of Furnace No. 3 for January, February and March, 1905. During these months dry-blast was held very steady in moisture and in temperature, the former being between 0.5 grain and 1 grain, with an extreme variation of 0.5 grain, and the latter between 5° and 15° F. (average, 10° F.), with an extreme variation of 10° F.

The coke-consumption of Furnace No. 3 for these three months with 50 per cent. Mesabi ore, producing basic low-silicon iron, was:—January (1905), 1,824; February, 1,815; and March, 1,787 pounds.

After this period, the dry-air plant was not able to hold its moisture as low, or its temperature as steady, for the balance of dry-blast run on Furnace No. 3, the effect being shown in Tables V. and VI.

TABLE V.—*Moisture Variation of Dry-Blast, Furnace No.* 3.

April, 1905, 0.5 grain to 1.75 grains—Extreme variation : 1.25 grain.
May, 1905, 0.75 grain to 2.25 grains—Extreme variation : 1.5 grain.
June, 1905, 1.25 grain to 2.50 grains—Extreme variation : 1.25 grain.
July, 1905, 1.00 grain to 2.25 grains—Extreme variation : 1.25 grain.

TABLE VI.—*Temperature Variation of Dry-Blast, Furnace No.* 3.

*April, 1905, 10° to 25°—Actual average 17°—Extreme variation : 15°
May, 1905, 15° to 30°—Actual average 25°—Extreme variation : 15°
June, 1905, 20° to 30°—Actual average 30°—Extreme variation : 10°
July, 1905, 15° to 30°—Actual average 23°—Extreme variation : 15°

* Dry-blast conditions were better in April on account of the lower moisture of the outside atmosphere than in the following months.

The coke-consumption of Furnace No. 3 during these months with 50 per cent. Mesabi ore producing Bessemer high-silicon iron, was:—April (1905), 2,083; May, 2,032; June, 1,973; and July, 2,081 pounds.

It will be noted that June, showing the lowest coke-consumption, has the least variation in the temperature of the dry-blast. The difference in fuel-consumption for these months between natural- and dry-air blast was less than the average practice, for the reasons given below.

The disturbing factors during these four months of 1905 were troubles at the furnace due to accidents and repairs, and to the leakage of bosh-plates. Moreover, the furnace used, during that time, a large proportion of very fine ore and made a higher silicon iron. During this period, the refrigerating apparatus was less effective, owing to the leaking of ammonia through the stuffing glands. This was unsuspected for a long time, as the apparatus had worked perfectly for the seven preceding months, and many other supposed causes were first investigated. When the true cause was finally discovered, it was very quickly remedied, as is shown by the results in the succeeding months of Furnace No. 1 (the dry-blast being changed from Furnace No. 3 to No. 1 in August).

In practice, a variation of 0.12 per cent. in the silicon has been found to be brought about by a change of 1 per cent. of the burden. Producing basic iron with 1 per cent. and Bessemer iron with 1.5 per cent. of silicon, gives $0.50 \div 0.12 = 4.17$ per cent. decrease in the burden; or 2.08 per cent. increase in coke, since ore-burden to coke-consumption is approximately as 2 to 1. The average coke-consumption during the first three months of 1905 for Furnace No. 3 was about 1,800 lb. per ton of pig-iron produced; 2.08 per cent. of this is an increase of 37 pounds. In Furnace No. 3, the coke-consumption on Bessemer iron during April to June, 1905, was 2,080, or 280 lb. higher than in the first three months. Deducting from this 37 lb., due to the higher silicon, leaves 243 lb. more coke consumed, due to furnace irregularities and poor dry-blast conditions. As neither of the two factors of fine ore and high silicon changed the results materially when they occurred during natural-air periods, I do not consider them as very serious factors in raising the coke-consumption in this case; but the furnace conditions would affect the results seriously, as would also the poorer dry-blast conditions.

Comparing the foregoing with Furnace No. 1 while on dry-blast, we find the following:—

TABLE VII.—*Moisture Variation of Dry-Blast, Furnace No.* 1.

August, 1904, 1.50 grains to 2.00 grains—Extreme variation: 0.5 grains.
Sept., 1904, 1.00 grains to 2.00 grains—Extreme variation: 1.5 grains.
Oct., 1904, 1.00 grains to 1.5 grains—Extreme variation: 0.5 grains.
Nov., 1904, 0.75 grains to 1.25 grains—Extreme variation: 0.5 grains.
Dec., 1904, 0.75 grains to 1.00 grains—Extreme variation: 0.25 grains.

Very few variations above or below these figures.

TABLE VIII.—*Temperature Variation of Dry-Blast, Furnace No.* 1.

Aug., 1904 (20 days), 15° to 30°—Actual average 22°—Extreme variation: 15°
Sept., 1904, 5° to 25°—Actual average 16°—Extreme variation: 20°
Oct., 1904, 10° to 20°—Actual average 18°—Extreme variation: 10°
Nov., 1904, 15° to 20°—Actual average 18°—Extreme variation: 5°
Dec., 1904, 10° to 20°—Actual average 18°—Extreme variation: 10°

Very few variations above or below these figures. In September, temperature and moisture variations were greatest, but temperature was very low and coke-consumption was 1,754 lb. for that month.

The coke-consumption on Furnace No. 1 with dry-blast on basic low-silicon iron, 50 per cent. Mesabi ore, during these months was:—

In August,	1904 (20 days),	1,753 lb.
In Sept.,	1904,	1,754 lb.
In Oct.,	1904,	1,862 lb.
In Nov.,	1904,	1,816 lb.
In Dec.,	1904,	1,823 lb.

Comparing this with the higher coke-consumption on Furnace No. 3 from April to July, 1905, and the dry-air conditions prevailing during those periods, it would indicate that more uniformity and steadiness of dry-blast conditions existed during periods of lower coke-consumption, and that the low temperature and the low moisture-content of the dry-blast, combined with the least possible variation, appear to give the best results for low coke-consumption.

The difference due to temperature variations under dry-blast conditions, as shown above, can be also shown as follows:—

At 18° F., 40,000 cu. ft. is 3,320 lb. of air per minute.
At 24° F., 40,000 cu. ft. is 3,276 lb. of air per minute.

That is to say, 44 lb. less air per minute (equivalent to 63,360 lb. per 24 hr.) are blown into the furnace by the same number of revolutions, under an increase of 60° F. in temperature. This represents about the difference between Furnaces No. 1 and No. 3 during the dry-blast periods.

This difference in the amount of air blown-in would affect the running of the furnace as follows:—under given pressure and temperature of blast, the more air blown-in per minute, the more rapid the combustion, and, consequently, the greater the heat of combustion, per unit of time. This rapidly increases the heat available for melting the material, and consequently diminishes the amount of actual fuel required to melt the same amount of material, through greater intensity of heat for more rapid and complete combustion, and through a greater concentration of heat in the fusion-zone, bringing the latter closer to the tuyeres, where its best effect can be obtained. This is true, of course, always within certain limits, dependent upon the capacity and condition of each separate furnace.

The general conclusions reached through a study of all available trustworthy data may be summarized as follows:

1. Increased blast-temperature alone cannot account for a decrease of 20 per cent. in the coke-consumption, and an increase of 20 per cent. in the product of pig-iron. There was no significant increase in blast-temperature at the Isabella furnaces while they used dry-blast; and the records of those blast-furnaces which show a low fuel-consumption are not, in general, characterized by a blast-temperature sufficiently higher

than that of the Isabella furnaces to account for their economy in fuel. This economy is doubtless due to innumerable local conditions,—such as character, richness and uniformity of ore, nature of fuel and flux, dimensions, shape and condition of furnace, perfection of machinery, intelligence and vigilance of management and working-force, etc., which every scientific furnace-manager takes into account in estimating the significance of his own experience, or comparing it with the experience of others. If all these elements of the problem could be made alike at all blast-furnaces, normal results of a given procedure could be at once determined, and any proposed change could be instantly weighed and judged. Such complete uniformity is obviously impracticable; but a device which operates in that direction, by removing all irregularity in a fundamental and most troublesome (though, hitherto, little regarded) factor, must recommend itself as an aid to those managers who have to deal with special local disadvantages in other respects, as well as to those who, by reason of fortunate conditions, are already making the best technical records.

2. The theoretically calculated effect of higher blast-temperature upon fuel economy, etc., though possibly realized in isolated cases, is not confirmed in general practice, which indicates a considerably lower net result. Our modern blast-furnaces, equipped with stoves for producing high temperatures of blast, have undoubtedly achieved much gain in product and fuel-economy, but not enough to equal the gains secured in those respects by drying the blast—gains, in fact, which can be added to those of such previous progress.

Thus, the proposition that an increase of 300° F. in blast-temperature would effect a decrease of 400 lb. in coke-consumption per ton of pig-iron produced is not confirmed by available records of practice, which indicate as the attainable saving from this source about 50 lb. of coke for each 100° F. of increase in temperature.

3. Of the furnaces using natural-air blast, it is usually the new ones that show high production with low coke-consumption. As the period of operation increases, the tendency to a reversal of these results becomes more and more evident. To this general rule, I have found few exceptions; and these were largely due to local conditions, not to be duplicated at other

plants. This point seems worthy of consideration, because the results thus far reported as to Mr. Gayley's invention were obtained from furnaces already a long time in operation, and far from perfect in general condition.

4. The advantageous results obtained from the dry-blast are not sensibly affected by changes of season. This method is equally efficacious at all seasons of the year.

5. With due allowance for local conditions, it may be safely inferred that, at furnaces averaging more than 2,100 lb. of coke per ton of product, from 10 to 20 per cent. of gain in product and of saving in fuel can be effected by the use of dry-blast. At furnaces already using less than this proportion of coke, the gain may be somewhat smaller. To what extent, for instance, the fuel-consumption of a furnace already making, on natural-air blast, a ton of pig-iron with, say, 1,850 lb. of coke, could be further reduced by artificially drying the blast, is a question to be settled by actual experiment.

6. Apart from all other theoretical gains realized by the desiccation of the blast, my study of the records of practice impresses upon me the predominant importance of the uniform and regular running of the furnace thereby secured. This may be said to have been ignored in scientific discussions of blast-furnace practice before Mr. Gayley's paper appeared. The desirability of removing moisture from the blast had been frequently suggested by technical authors, but the theoretical advantages to be thus realized did not seem to be commensurate with the expenditure involved. As Mr. Cochrane tersely put it, " the game was not worth the candle." It remained for Mr. Gayley to demonstrate a gain, not included in theoretical arguments, yet perhaps greater than any other therein considered: namely, that of uniform and perfectly controllable furnace-operation, and the consequent diminution of the amount of superfluous fuel hitherto carried as a "margin of safety," to meet the unforeseen contingencies of the "behavior" of the blast furnace. This element has never been definitely measured in estimates of cost; but it is probable that every furnace manager would rate it above most others, as a factor of actual business cost.

DISCUSSION.

H. M. HOWE, LL.D., New York, N. Y.:[6]—The greater regularity of furnace-working, emphasized as the most important cause of the economies attending the Gayley dry-blast process, furnishes, in my opinion, an explanation which does not explain, since it leaves the question still to be answered, how and why the fuel-economy ascribed to this regularity can be so astonishingly great.

In the decades during which I have had to do with actual metallurgical manufacture as learner, then superintendent, then manager, then and still active director, the importance of regularity has indeed been impressed on me. It was long my habit to wake and time the revolutions of the engines against my pulse-beats, so as to assure myself of the needed regularity. But regularity, in and by itself, does not in the least explain why the fuel-economy which it gives is so astonishingly great. It simply pushes the difficulty one step farther back, leaving it really wholly unexplained. But the explanation is readily found if we take up the line of reasoning indicated by Mr. J. E. Johnson, Jr.,[7] and push it beyond the point at which he left it.

In brief, the economy of the dry-blast process, like that of the hot-blast process, is due essentially to its widening the margin between the temperature developed by combustion and what Mr. Johnson calls the "critical" temperature, *i.e.*, the temperature at and above which certain essential work of the blast-furnace process must be done. To the term "critical temperature" it may be objected that this term has already been appropriated by physicists for another meaning. The objection has some force, and a term without a dual meaning would be better. But after all "critical" is a broad, generic adjective, too valuable to be restricted to any narrow specific sense.

Adopting this term for lack of a better, it is true, as Mr. Johnson points out, that, for the work which has to be done above this critical temperature, the only heat available is that which the gases can give out in cooling to this temperature from their combustion-temperature, *i. e.*, the temperature to which the combustion in the hearth of the furnace raises them; because, once they have cooled to the critical temperature, their remaining heat is no longer available for work above that temperature. The economy of the dry-blast process, like that of the hot-blast process, is essentially due to the fact that each of these processes raises the temperature which the combustion in the hearth gives to the gaseous products of that combustion, and thus widens the margin between the combustion-temperature and the critical temperature; and it is the width of this margin that, in a rough way, measures the degree to which the heat generated can be utilized. If the critical temperature is 1,200° C. and the combustion-temperature 1,300°, there is a margin of only 100°; raise the combustion-temperature by 100°, or by only 8.5 per cent., and you double the margin, and increase in a corresponding proportion the utilization of the heat.

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[6] Professor of Metallurgy, Columbia University in the City of New York.

[7] Notes on the Physical Action of the Blast-Furnace, *Trans.*, xxxvi., p. 454. Mr. Johnson called my attention to the importance of this line of thought several years before the disclosure, but not before the invention, of the Gayley process.

It is like the case of water running over a waste-weir in the side of a canal. If the depth of the stream of water is originally 50 in., and the level of its upper surface 1 in. above the bottom of the waste-weir, and if the depth of the water is then increased so as to raise the level of its upper surface by 1 in., then, although the volume and depth of the stream as a whole are increased only 2 per cent., yet the water available for flowing through the waste-weir is increased 100 per cent. The level of the waste-weir is a "critical" one; and the depth of water available for the waste-weir is the depth above that critical level.

Or it is like utilizing the heat in a stream of hot gases to heat and boil water in a system of boilers and feed-water heaters, assumed for simplicity to offer such extended surface to the passing gases as to give ample opportunity for extracting from those gases all the heat which they are theoretically capable of giving up. If the water enters the heaters at 0° C. and is boiled at atmospheric pressure at 100°, then 100 calories are needed to heat each kilogram of water up to the boiling-point, and 536 calories to boil it. If now the hot gases enter the system at a temperature of 101°, they can give up to the work of boiling the water only 1°, or about 1 per cent. of their heat, because when they have cooled from 101° to 100° they have ceased to be able to transfer any more heat to water itself at the boiling-point, 100°. They then pass on to the feed-water heaters, still containing about 99 per cent. of their initial heat. But all the useful work that they can do in these heaters is to preheat just enough water to take the place of that which they have just boiled away in the boiler. And as the heat needed in raising the water to its boiling-point is only 100-536ths, or about one-fifth, of that needed for boiling that same water, and hence as the work of preheating in the feed-water heaters is only about one-fifth that of boiling in the boilers, the heaters can use only about one-fifth as much of the heat of the gases as the boilers do, or only about one-fifth of 1 per cent. of the initial heat of the gases. So that the total percentage of the heat of the gases which can be utilized in the system of boilers plus heaters is only about 1.2 per cent. The rest of their heat the gases must carry away out of the system ; and this heat must therefore be wasted.

If, on the other hand, the initial temperature of the gases is 636° C., then in passing through the tubes of the boilers they are capable of giving up to the work of boiling 536° of their heat, and of thus being cooled to 100° ; passing thence to the feed-water heaters, they can there give up the remaining 100° of their heat to the work of preheating the water which is to replace that which they have just boiled away in the boilers. And, because the heat needed to preheat a kilogram of water is to that needed for boiling it as 100 is to 536, therefore the 100° remaining in the gases as they enter the heaters is just sufficient to preheat to 100° the quantity of water which will exactly replace that which the gases boiled away in the boilers in their act of cooling from 636° to 100°.

Yet while Mr. Johnson's general explanation is correct, his ideas need to be much more carefully defined; and it is the need of this work of definition which leads me to prepare these remarks.

In order that the width of the margin between the working-temperature and the initial temperature of the gases shall be important, it is essential that the heat needed at and above that working-temperature shall be greater than at the average of lower temperatures. To make this clear, let us take the case of simply heating water up to its boiling-point, but without boiling it. Here, assuming that the specific heat of the water and of the gases respectively is constant and does not change with the temperature, then, so far as the theoretical efficiency of the heating-process is concerned, the heat of the gases can be utilized as fully if their initial temperature is 101° C. as if it is 1,001°. All that is necessary is that there shall be some margin between the initial heat of the gases and the temperature to which they are to heat the water; and the width of that margin is in one sense absolutely unimportant.[8] To heat 1 kg. of water from 1° to 100° takes 100 calories. If we take the specific heat of the gases as 0.25, their initial temperature as 101°, and their final temperature as they pass out of the heater as 1°, then each kilogram of gas, in cooling from 101° to 1°, gives out $100 \times 0.25 = 25$ calories, and therefore $100 \div 25 = 4$ kilograms of gas are needed for each kilogram of water. If the gas starts in at 1,001° and escapes at 1°, each kilogram of gas in cooling gives out $1{,}000 \times 0.25 = 250$ calories, and therefore only $100 \div 250 = 0.4$ kilograms of gas are needed for each kilogram of water; or one-tenth as much gas as in the previous case. But the heat in 1 kilogram of gas at 100° is the same as that in 0.1 kilogram at 1,000°; and, so far as the needs of the operation are concerned, a given calorie can be used as efficiently in one case as in the other. This is essentially because the water, in each degree of its rise from 0° to 100°, needs the same quantity of heat; and the gases in cooling through each degree from 100° to 1° give out the same quantity of heat; so that, assuming that our walls are perfect conductors of heat, it is only a question of proper mechanical arrangements to transfer the heat given out by the gas in cooling from 101° to 100° to water which is simultaneously rising from 99° to 100°; and the heat which the gas gives out in cooling from 100° to 99° to water which is simultaneously rising from 98 to 99°, and so on. If this mechanical arrangement is perfected, the whole of the heat given out by the gases in thus cooling from 101° to 1° can be utilized and absorbed in heating water from 0° to 100°.

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[8] For simplicity of presentation I have purposely ignored some very evident and important practical considerations, such as that the wider the temperature-margin between the gases and the body which they are heating, the more rapidly and thoroughly will the transfer of heat take place. The assumption that the walls of the boiler and of the feed-water heater conduct heat perfectly, and the tacit assumption that the outer walls of the furnace are adiabatic, of course, are made only to simplify the discussion.

But, if the water has not only to be heated to 100°, but also boiled at 100°, then only the heat in the gases above 100° is available for that boiling; and, in order that the heat which those gases contain after cooling to 100° shall be utilizable in the work of heating the water up to 100°, the quantity of gas must be so small that the water in rising from 0° to 100° shall be capable of absorbing all that heat; and in order that the quantity of this gas which shall have boiled a given quantity of water shall be small, its initial temperature before it began transferring its heat to the work of boiling must be high.

Hence the need of a wide margin of temperature between the initial and the working-temperature in processes which, like the boiling of water, have a critical temperature; and the relative unimportance of the width of that margin in processes which, like the simple heating of water, have no critical temperature.

The reason why the importance of the margin between the initial gas temperature and critical temperature has generally been overlooked is that, in most of our heating processes, the margin is naturally so very wide that slight current variations in its width are unimportant. It is the natural narrowness of this margin in the blast-furnace process that gives to the hot-blast and the dried blast their very great value, and will some day give a still greater value to processes for lessening the nitrogen in the blast.

From these considerations I deduce the formula given below.

If we let t_c = the critical temperature; t_i = the initial temperature of the gas (which is usually its combustion-temperature); h_c = the heat needed at and above the critical temperature, and h_b = the heat needed for raising the materials to be heated to the critical temperature; then in order that the heat shall be thoroughly utilized, and may be thoroughly recovered from the escaping products of combustion, it is necessary that the initial gas-temperature should be at least as high as is called for by the formula

(1) $(t_i - t_c) : t_c = h_c : h_b$, whence

(2) $t_i = t_c \left(1 + \frac{h_c}{h_b}\right)$.

Or, if we take into account the variations in specific heat, and let S_c = the mean specific heat of the gases between the critical temperature and their initial temperature, and S_b = their mean specific heat between the critical temperature and that of the atmosphere, then for formula (1) we should substitute:

(3) $(t_1 \times S_c - t_b \times S_b)$; $t_b \times S_b = h_c : h_b$, and for equation (2),

(4) $t_1 = \frac{t_c}{S_c} \left(1 + \frac{h_c}{h_b}\right)$.

The matter may be made clearer to some by looking at it in another way. Let us put out ourselves in the position of one using the dry-blast process, and then see what effect on the fuel-consumption ought to be expected as the result of adding moisture to the blast. This not only calls for extra fuel to supply the extra heat needed for heating and dissociating this moisture, but (like cooling the blast or diluting it with additional nitrogen) by lowering the temperature which combustion develops, it narrows the already narrow margin between that temperature and the critical temperature, above which a very much larger quantity of heat is needed to make good the absorption due to the latent heat of fusion of iron and slag, and probably of deoxidizing silica and lime, than is needed at the average of lower temperatures. The combustion-temperature with moist-blast in Mr. Gayley's practice seems to be further lowered, and this margin thereby further narrowed, by a decided lowering of the blast-temperature due to the fact that, with the hot-blast stoves used, the larger quantity of blast needed could not be heated so hot, although the gas used for heating it seems to have increased in quantity proportionally, and to have improved in quality. This part of the narrowing of the temperature-margin might perhaps be made good by enlarging the hot-blast stoves.

If the narrowing of this margin is to be atoned for by burning more fuel, then of the heat generated by that fuel only that corresponding to the narrowed margin between the combustion and the critical temperatures can be utilized. Of that represented by the range of temperature below this, we see no strong reason to expect that any important part can be recovered from the products of the combustion of this extra fuel by the descending solids, nor can the carbon monoxide generated by this extra fuel be converted into carbon dioxide by those solids, because, even with hot and dried blast, the power of those solids to absorb heat and to oxidize carbon monoxide appears to be already fully utilized, so that we have no strong reason to think that they can do more in either respect. This extra quantity of carbon monoxide and this extra heat may therefore be expected to be present in the gases when they escape from the top of the furnace; and these gases should therefore both be hotter and have a lower ratio of CO_2 : CO with moist than with dried blast. Indeed, the quantity of carbon monoxide in the escaping gases should be even greater than this would imply, because, being hotter, their carbon dioxide should react the more energetically upon the entering coke, and thereby be reduced to carbon monoxide, and further increase the fuel consumption by thus dissolving away part of the entering coke, which must be replaced by more extra fuel.

Indeed, the matter is still worse. Narrowing the margin between the combustion and the critical temperatures lessens the thoroughness with which even the heat represented by the narrowed margin can be utilized even for the critical work, first because the cooler gases transfer their heat to the solid and molten matter less rapidly because of the narrowed temperature-margin between them, and next because, thanks to their greater weight and hence volume, they pass more rapidly by that matter. The heat transfer is slower, and the time allowed for the transfer is shorter.

This statement in reverse, so to speak, is taken with some modification from a more extended discussion of the whole subject,[9] and to which I refer those who may care for my views on this interesting question.

JOSEPH W. RICHARDS, Bethlehem, Pa.:[10]—Mr. Meissner's interesting communication confirms the statements of the former papers presented to the Institute by Mr. Gayley, and while practically proving the facts beyond peradventure, challenges the scientific world for a satisfactory explanation. The weight of opinion, as expressed by Mr. Gayley and others who have discussed the subject, is that the increased regularity of working of the furnace blown by dried air is the all-important cause of the economy obtained. This statement, however, is no explanation of the matter; and the question at once arises as to why increased regularity is obtained, and why irregularities occur if the blast be not dried. If a new administration of a railroad obtains better results by increasing the regularity of running of its trains, it is a true statement to say that the greater capacity of the railroad is due to increased regularity of operation; but the real question is, "How has the increased regularity been obtained?"

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[9] *Iron, Steel and Other Alloys*, 2d edition, 1906, Albert Sauveur, Cambridge, Mass., pp. 457 to 475.

[10] Professor of Metallurgy, Lehigh University, South Bethlehem, Pa.

By regularity of operation is meant uniformity of temperature before the tuyeres, uniformity of grade of iron made, and uniformity of amount of output. It is admitted that the ordinary furnace is subject to irregularities in these respects; in fact, to such suddenly occurring irregularities that it is necessary to forestall them by providing always enough fuel in the charge to meet the worst irregularities which may occur. It takes about 24 hours for a change in the burden charged to have an effect at the region of the tuyeres, while serious irregularities may occur within 6 or even 3 hours, which it is therefore impossible to meet promptly by changing the burden. Under these conditions, it being necessary to be always "prepared for the worst," the blast-furnace manager is not foot-free to take full advantage of the most favorable conditions. If he can, therefore, be assured of uniformly favorable conditions, such as drying the blast provides, he can dispense with the ordinary margin of insurance against unfavorable conditions, and run uniformly with the lowest possible fuel-charge. It is, therefore, absolutely true that the uniform conditions obtained by drying the blast do enable the blast-furnace manager to economise: the real solution or explanation of the ultimate "why?" has, however, still to be given.

The true logic of the situation is this: the uniform conditions obtained by drying the blast would produce no economies if they were not *uniformly favorable* conditions. If the conditions were such as to be uniformly the worst which could occur, the blast-furnace manager would have uniformity, but no one will maintain that he could economize thereby. Drying the blast produces uniformity of the *favorable* type; and this is the only kind of uniformity which will assist the manager. With blast not dried, the non-uniform conditions which cause unfavorable irregularities are the varying temperature and moisture-content of the outside air. With cold, dry air the furnace does its best; with warm, moist air it does its worst; sudden changes cannot be altogether foreseen; and, therefore, the manager must always be prepared for them by using a large fuel-ratio in the charge. The dry-blast provides the uniformly *favorable* condition, and therefore gives the basis for the economies realized. The whole question thus resolves itself into the query, "Why is the use of dried blast, of uniform composition and low temperature, better than the use of moist blast of non-uniform composition and varying temperature?"

The real explanation is two-fold. One reason is, that with blast of uniformly low temperature coming to the blowing cylinders, more oxygen is pumped into the furnace per day, thus increasing the rate of driving, other conditions remaining fixed; the second reason is, that the absence of moisture in the dried blast results in a higher temperature in the region of the tuyeres, thus increasing the reducing-power and smelting-down capacity, and incidentally inducing several other favorable conditions.

It needs no argument to show that, if the engines are running uniformly, the amount of oxygen drawn into the cylinders (independent of the amount of moisture in the air) is a function of the temperature, varying inversely as the absolute temperature (from -273° C. or -458° F.) Air at 0° C., for instance, contains 10 per cent. more oxygen than air at 30° C., and therefore, with engines running uniformly, 10 per cent. more carbon would be burned at the tuyeres, per day, with air at 0° C. than with air at 30° C.—altogether aside from any question of moisture. If the air at the two temperatures named did contain identical quantities of moisture, the temperature at the tuyeres would be practically the same, in the two cases, and the ore smelted per day would be a little more than 10 per cent. greater with the cold air, because the greater speed of running would reduce radiation-losses and slightly increase the smelting-power of the furnace per unit of fuel burnt at the tuyeres.

The second reason, and the most important one, has been discussed at length by me in a paper already published.[11] I will here re-capitulate the results of that analysis, referring for details to the original paper. Taking the two conditions, ordinary blast and dried blast, as described by Mr. Gayley, the temperature before the tuyeres is calculated as 1,861° C. with ordinary blast and 1,965° C. with the dried blast, a difference of 104° C. or 187° F., which difference results in an increased smelting-power and reducing-power in the region of the tuyeres. The absence of the moisture produces the higher temperature, there being available for smelting-down purposes 11,287 calories more, an amount equal to 23.4 per cent. of all the heat needed to smelt-down the pig-iron and slag. This extra heat, available just where it is most needed, while representing only 3 per cent. of the total energy of the coke put into the furnace, yet represents 23.4 per cent. of the energy of the coke which is generated and available for smelting-down purposes in the region of the tuyeres, for the simple reason that only from 20 to 30 per cent. of the power of the fuel is, in any case, available for smelting-down in the tuyere-region.

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[11] *Bi-Monthly Bulletin*, No. 4, July, 1905, page 703.

Another way of looking at the matter and arriving at a similar conclusion, is to itemize the saving obtained by using dried blast. The saving of fuel per 100 of pig-iron produced amounted to:

	Per Cent.
On decomposition of moisture of heat,	2.95
On heat in waste gases,	5.25
On lessened radiation,	3.70
On better combustion of carbon to CO_2,	6.90
On smaller heat in slag,	0.10
On less heat in blast,	0.40
	19.30

This tabulation tells us just how and where the dry blast effects its economies. The direct saving, by removing moisture, is relatively small, but this heat is saved at such a vital spot in the furnace, that the remaining 15 to 20 per cent. of economy follows as a necessary consequence. The amount of carbon burnt at the tuyeres, per ton of iron produced, being reduced by the higher temperature available, the amount of gases passing upwards per ton of charge is relatively decreased; therefore, their temperature on escaping is lower, and this lower temperature accounts for a saving of heat to the furnace amounting to 5.25 per cent. of the fuel ordinarily used. The smaller amount of carbon monoxide produced at the tuyeres per ton of iron reduced, produces better combustion above to CO_2 gas; for, since the ore has only a certain amount of oxygen to give up per ton of iron reduced, this oxygen will consume CO to CO_2, and the proportion of CO_2 to CO escaping must be larger, the smaller the amount of CO which there is in the furnace. This fact gives us the greatest single item of economy: 6.9 per cent. of saving in fuel being represented by the larger proportion of CO_2 to CO in the gases, because of the smaller amount of CO generated at the tuyeres. Radiation from a furnace is practically so much per day, and if we increase the output, the radiation for unit of product is decreased. This decreased radiation amounts to a relative saving of 3.71 per cent. of fuel.

Taking it all in all, therefore, we do not need to say that increased regularity explains the gains made by Mr. Gayley. The true answer is deeper seated: the dried blast produces regularity of the *uniformly favorable* type, as distinguished from an unfavorable uniformity. The reason why dried blast is more favorable than moist blast resides primarily in the fact of the higher temperature produced at the tuyeres. This smelts down iron and slag more quickly (increased rate of running) and more economically per unit of iron and slag produced. This economy of carbon burnt at the tuyeres causes a better combustion or utilization of CO above the tuyeres, decreases the temperature of the issuing gases, and relatively decreases radiation-losses. These uniformly favorable conditions give an advantage over uniformly unfavorable conditions, and practically an equal advantage over irregular conditions varying from favorable to unfavorable, under which the manager must run, allowing all the margin necessary to meet the most unfavorable condition should it suddenly occur.

Frank Firmstone, Easton, Pa.:—It seems very clear that most of the fuel saved by drying the air is due to indirect advantages, and Prof. Richards' heat-balance shows very satisfactorily the several heads under which this economy is distributed and the value under each. I think furnace-managers will generally admit that, of several furnaces not differing very greatly in size and shape and using identical materials, the one which works with the greatest regularity almost always (always in my own experience) will show the lowest fuel consumption. This follows chiefly from the fact that it is safe to burden such a furnace more heavily than can be done with one less reliable, a fact to which Mr. Gayley has himself referred.

It must be a great satisfaction to Mr. Gayley that his clear understanding of the probable gain, over and above the direct calculable gain from decreasing the water entering the furnace, has caused him to persevere to the attainment of such important results.

A word of caution may not be amiss in this connection. I believe it to be a fact that furnaces which tend to work regularly because of favorable conditions as to materials, shape or size, etc., show far less deviation from the normal, when subjected to a disturbing cause of given magnitude, than do those less favorably situated in these respects. I could cite fairly conclusive examples from my own observations. I have no personal experience with the materials now used in the Pittsburg district, but from conversations with blast-furnace managers from there, and from recent remarks in trade and technical journals, I think that furnaces which use them do not work with all the regularity desirable. If that be so, and admitting what is said above as to the greater effect of disturbing influences under such circumstances, it may easily happen that materially less advantage will follow the application of dried air to furnaces more fortunately situated in these respects than those around Pittsburg.

It is worth noting that although according to Prof. Richards' heat-balance, the dry-air furnace receives 1,535 less calories from the hot-blast than does the moist-blast, a decidedly larger proportion of the total heat comes from this source than in the moist-air furnace (10.26 per cent. in the moist air, 11.21 in the dry air). This is of the greater importance, because heat in the blast corresponds to carbon in the coke burned to CO_2, and not in large part to CO, as does the heat produced in the furnace itself.

We are apt, perhaps, to draw too positive conclusions from the apparent accuracy of the heat-balance, which after all is only a necessary consequence of the accepted doctrine of the conservation of energy. Not to speak of the present case, in which that portion of the gain arrived at indirectly greatly exceeds the part which could be pretty accurately calculated in advance, there have been plenty of instances in which a lucky change in methods of filling or more careful preparation of materials has resulted in gains almost comparable to those accomplished by Mr. Gayley, although what was actually done furnished, *a priori*, no grounds whatever to expect any change in the heat-balance.

R. W. RAYMOND, New York, N. Y.:—At the New York meeting of the Iron and Steel Institute,[12] I emphasized the uniformity of furnace-work secured by Mr. Gayley's invention as the chief element of its technical and commercial value; and I have seen no reason since that time to change this opinion.

Mr. Meissner has shown that the greater liability to wasteful irregularities involved in the use of a variable natural-air blast requires, as a necessary (yet still incomplete) safeguard, an excess of fuel, constituting, as it were, a reserve of heat for emergencies. This suggests a partial analogy, drawn from another branch of engineering, namely, the so-called "factor of safety," employed in all constructions, by which the theoretically sufficient dimensions of a given piece of material are multiplied, in order to provide for unexpected strains or undetected weakness. In the building of the first Brooklyn Bridge, the factor of safety for the wires of the suspended cables was reduced considerably below the traditional figure, for the simple reason that the wire for those cables had been so carefully manufactured and so thoroughly tested, piece by piece, as to remove the danger of unsuspected weakness, and measurably to insure the behavior of the material in practice, according to the formulas of tensile strength and elasticity assumed for it. By such a legitimate reduction of the factor of safety, much money was saved in construction.

The extra coke, charged in a blast-furnace as a "factor of safety," is not, I confess, a perfectly parallel case. For the extra material put into wires or beams to provide for human oversight or exceptional emergency, simply stays there, drawing interest on its cost; whereas the extra fuel in a blast-furnace is burned, anyhow, whether it be needed or not. If it be not needed to meet sudden heat-requirements, its combustion must produce further irregularities in zones of reduction and fusion, grade of product, etc., or an increased proportion of CO and an increased temperature in the tunnel-head gases. This raises another question, into which I do not propose, at this time, to enter. We all remember that the illustrious Sir Lowthian Bell, whose memorable investigation and discussion of the blast-furnace process will be forever a classic authority, practically reached the conclusion (destructive at that time to many academic theories) that the blast-furnace process for the production of pig-iron was so admirably fitted for its purpose as to furnish, for a given ratio of CO to CO_2 in the escaping gas, the best internal smelting-results, together with sufficient and suitable fuel for heating the blast and raising steam in the boilers. Such a conclusion can never be final. The value of furnace-gases for use outside of the furnace itself (whether in making steam, in heating blast, or even—as Westman proposed—in calcining ore) has steadily declined in the opinion of iron-masters with the enormous increase in the product of each modern blast-furnace itself. In comparison with the quantity and quality of that product, they care much less now than formerly whether outside heat-requirements are supplied from the furnace-gases or not. There are many ways of getting heat for boilers, stoves and kilns, from fuel generally cheaper than that which is charged into the blast-furnace. And if any improvement in the smelting-process proper should, by reducing the amount of superfluous fuel used as a "factor of safety," require additional heat for outside purposes, we could easily help ourselves. Moreover, such an excess of fuel carried within the furnace is likely to do least good outside, just when it is most needed.

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[12] October, 1904; see *Journal of the Iron and Steel Institute*, lxvi., No. 2, 1904, p. 301, and *Trans.*, xxxv., 746, 1022.

The immense practical importance of eliminating irregularities from metallurgical operations is illustrated in many other departments, besides those of iron and steel. To name only one example, the chief advantage of the modern reverberatory furnaces for the matte-smelting of copper-ores, the dimensions of which have paralyzed with astonishment those of us who painfully mastered the principles of copper-smelting a generation ago, seems to be the removal (through the presence of a vast reservoir of heat in the molten charge) of those frequent changes of heat-conditions, through charging and discharging, which were inevitable in operations on a smaller scale.

In the manufacture of pig-iron, the increased capacity of the blast-furnace has illustrated the same principle. A hundred little problems of the practice of the last generation have been, not solved, but actually drowned out of sight, by the high blast-temperature, rapid running, and great mass of stock in all stages of reduction, presented by our great modern furnaces. On the other hand, any irregularity of furnace-work means at least ten times as much loss of money as formerly. No matter how effective the scientific remedy may be, the manager of to-day cannot afford the cost of the temporary furnace-disease. His one prayer is, that he may know what he has to do, and what he is doing, and that he may not be overtaken by surprises—any one of which might cost him more than many theoretical improvements could recover for him.

Such calculations as Prof. Howe and Prof. Richards have given us are unquestionably of the highest value. But I do not think they discredit the importance of the principle of regularity as a source of economy. To use Prof. Howe's expression, they simply explain how and why regularity produces the results observed.

The argument of Prof. Richards suggests another analogy with constructive engineering, namely, that of the placing of material just where it is needed, instead of wasting it elsewhere—as illustrated by the old-fashioned wooden bridges built by rural carpenters, all parts of which were of the same size, or even by the famous Brooklyn Bridge itself, the four cables of which have the same diameter, though two of them carry more than twice as great a load as the other two. Such an economical distribution of material in a structure is practicable in proportion as the strength of each part, and the uniform amount or limits of variation of the strain upon it, are known. The necessity of a vaguely determined "factor of safety" is a hindrance. In a similar way, it seems to me that the measurable elimination of such a factor in the heat-supply of the blast-furnace permits the heat to be supplied at the point where it will be theoretically most effective, instead of points where it may be accidentally needed, but is normally less useful, and sometimes, in certain respects, harmful.

But this is not all. Within certain limits, uniform conditions are, *per se*, more economical in practice than fluctuating conditions. The latter prevent a furnace from working up to any formula of efficiency that may be framed for it, no matter with what liberal allowances for contingencies. Nobody can tell what may be the loss of time, labor, material, quantity or quality of product, caused by a single episode of irregularity in working. Regularity does more than secure a regular income. It protects the furnace against sudden, premature death. Since the cost of re-lining, etc., for a new campaign must be repaid with interest by the product of that campaign, the length of the campaign is an important element of economy.

In short, I do not see that there is any essential difference between Prof. Howe and Prof. Richards, on the one hand, and those who have emphasized uniformity as the fundamental advantage of Mr. Gayley's invention, on the other. They analyze the advantages derived from a uniform dry-blast, and due to its dryness (*i.e.*, to the smaller amount of moisture, the larger proportion of oxygen, etc.); while we think there is a controlling practical advantage in its uniformity—a condition which their calculations necessarily assume. In other words, if we imagine a blast-furnace situated in a climate which furnished a natural blast even lower, on the average, in moisture than Mr. Gayley's dry-blast, but varying, between day and night, from far below to far above that limit, we think the variations would more than counterbalance the practical economy of the more favorable *average* conditions.

At all events, I am warranted by this discussion, and by previous discussions in this country and abroad, in expressing the pleasure which, I do not doubt, is shared by all my American colleagues in the fact that the consideration of this new advance in metallurgical practice has already passed beyond the stage of skepticism as to its practical results, into the stage of serious, scientific inquiry concerning their explanation. This is the normal and proper course for such testing of new technical propositions. The exceptional feature in the present instance is the brevity of the initial period of incredulity, which I regard as a generous, and, at the same time, a just recognition of American representatives of both the science and the practice of metallurgy.

JAMES GAYLEY, New York, N. Y.:—Whether or not the increased uniformity obtained by the use of dry air explains the economies thereby effected, it makes possible, nevertheless, the various theories brought forward to account for those economies. It is a fact well known to all furnace-managers, that, owing to atmospheric conditions, there are a great many days and periods when the furnace could be operated much more economically than it is, the conditions being such as to permit of a material increase in burden; but instead of meeting these conditions, the blast-temperature is reduced, and often the volume of blast is increased, in order to gain a temporary advantage through increased output. A change in burden is not practicable, because, too frequently, before the larger burden could reach the tuyeres, a change in atmospheric conditions might occur and the fuel-consumption would be increased above the normal amount by reason of a derangement of the furnace. Thus, by reason of the lack of uniformity in the ever-changing humidity of the atmosphere, advantageous conditions could not be utilized, because they were temporary.

The drying of the air not only removes an unfavorable and varying element from the blast, but by keeping the content of moisture in the dry air practically uniform, through refrigeration to a uniform temperature, it permits the delivery into the furnace of a practically constant weight of air, and therefore of oxygen—a result which cannot be obtained through an increase in blast-temperature. The elimination of the moisture removes a heat-extracting element at the tuyeres—a critical point in the furnace-operations—and this, together with the uniform weight of oxygen constantly supplied, intensifies the combustion, and localizes and lowers the fusion-zone. With natural air the fusion-zone is constantly fluctuating; when the zone is lowered, incipient scaffolds form on the area through which it is lowered; and when the zone is again raised, these scaffolds are melted loose, and, descending into the hearth, absorb heat. For this purpose alone, a margin of safety in fuel must be carried in the burden.

Before this process was applied practically, many calculations, made to determine the economic value of a removal of the moisture, indicated that, during the spring and autumn periods, a saving of from 3 to 3.5 per cent. in fuel could be obtained;

while during midsummer a saving of 7 per cent. was possible. Yet the saving actually realized has been from 15 to 20 per cent., according to conditions. That uniformity, in the weight of air delivered to the furnace, is the greatest factor making for economy, is shown by the fact that quite as great a saving has been effected in the dryest months of winter as in the more humid months of summer.

Prof. Richards observes that the removal of moisture primarily produces a higher temperature at the tuyeres and thereby effects various economies. When Mr. Windsor Richards, an acute observer of metallurgical processes, visited the Isabella furnace, he immediately noticed and called attention to the intense brightness of the tuyeres. Prof. Richards hits the nail squarely on the head when he says that dry-blast "produces regularity of the uniformly favorable type."

Mr. Firmstone says there are many instances in which "a lucky change in methods of filling or more careful preparation of materials" has produced great and valuable gains in blast-furnace practice. I believe this to be true in his experience, which is to-day still greatly valued by all blast-furnace managers, and I know it to be true in my earlier experience; but I do not think it is true of the practice of the past ten years. Mr. Firmstone remarks that, from conversation with blast-furnace managers in Pittsburg, with reference to the materials used, he thinks "that furnaces which use them do not work with all the regularity desirable." I think Mr. Firmstone has reference to the early use of Mesabi ores, with regard to which the statement is true. In a given unit of time, Mesabi ores will part with from 25 to 28 per cent. while the Old Range Lake Superior hematites will only part with 15 to 22 per cent. of their oxygen to form carbonic oxide gas; and this difference in reducibility has caused considerable irregularity in furnace-operations. (I question if anyone has so thoroughly investigated reducibility of American iron-ores on a practical scale as Mr. F. E. Bachman, of Port Henry, N. Y., from whom I have obtained my data.) But we have learned much in a few years; and under the practice of charging a furnace with ores of nearly uniform reducibility this trouble has disappeared. Moreover, it should not be overlooked, that the economies effected by dry-blast, as reported in my previous papers, were realized with furnaces which had been using 50 per cent. of Mesabi ore for several years and working with as much regularity as I have found anywhere in my experience. The comparisons made by me were therefore fair in this respect, being based upon indentical conditions—aside from the nature of the blast—in the records compared.

Let me suggest now certain economies, both practical and theoretical, in the application of dry-air blast. The plant at Isabella was designed solely to determine the value of dry-air blast, with a minimum of expenditure. Only one refrigerating-chamber was provided. It would have been better to divide this chamber by partitions, with an outlet from each division to the blast-main, that could be closed during the thawing-off period. Every day, one-third of the coils are thawed off; and, with the present construction, the quantity of moisture in the air supplied to the blowing-engines during this process is increased 50 per cent., as is shown in Fig. 1.

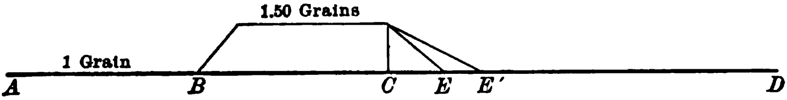

FIG. 1.—MOISTURE IN DRIED AIR, USING ONE REFRIGERATING CHAMBER.

Let *A* to *D* represent 24 hr. We begin at *B* to thaw the coils and are running at 1 grain of moisture per cu. ft. of air; at *B* it increases to 1.50 grain, the thawing is completed at *C*, but the chilling-effects of that 0.5 grain of water (which represents the delivery into the furnace of 18 gal. of water per hr.) is not ended at *C*, but continues to a point represented by *E* or *E'*. We have therefore practically, under present conditions, out of the 24 hr. only 16 hr. of normal conditions as to moisture. By means of sub-chambers, we shall be able to run on a regular content of moisture, and I contend that the best work obtained at the Isabella plant, will, through the future employment of sub-chambers in construction, eventually prove to be the normal condition of work.

From theoretical calculations, it appeared that an economy in construction could be effected by conducting the operation in two stages; that is, by passing the air first over coils cooled to 30° F., and condensing a considerable portion of the moisture as water, after which, by passing it over a series of coils at a much lower temperature, it could be reduced to the desired temperature, while the moisture would be deposited as frost. Since the water from the first cooling would flow away, thus leaving a smaller amount of frost to be removed by thawing, this arrangement seemed advantageous. But when the data were supplied to manufacturers of refrigerating machinery, the estimates they furnished showed that there would be actually no economy in construction, and the saving in operation was indicated to be very small. The two-stage system appears to be more difficult of adjustment to varying conditions, and to involve more complications in operations—which are not desirable, since economy of power would depend on the proper adjustment of the two stages.

The use of ammonia by direct expansion in the refrigerating-chamber requires, in comparison with brine, more expensive pipes and fittings in construction, and more careful oversight in adjusting the valves to secure a uniform refrigeration. According to theoretical calculation, the direct expansion shows an economy over the brine system; but I doubt whether this would prove true in practice. Our first installation with direct expansion at the Isabella furnace showed that additional labor would be required. We are now using, with the brine-system, two men on day-turn and one man at night, while with direct expansion four men would be required for the two turns. Direct expansion presents, moreover, additional opportunity for increased leakage of ammonia.

My first experiment was conducted on the two-stage system. The air was taken in a heated engine-room in winter, and cold river-water was passed through one chamber and ammonia directly expanded through another; and (in the last experiment before the installation at the Isabella furnace) two large chambers were used, in one of which brine was circulated, while in the other ammonia was directly expanded.

It has been suggested that the cold air passing from the refrigerating-chamber could be conducted to a regenerator, to cool the incoming air. This would increase the cost of construction, and does not hold out much promise of economy in the refrigerating operation. The dry air, being heated by this operation, would require more revolutions of the blowing-engines to deliver the required weight of air to the furnace; and this would consume more power. But the chief objection is, that the dry air, absorbing heat from the incoming air, would vary in subsequent temperature nearly as much as the natural air, and the process would thus, to a considerable extent, revert to natural-air conditions. Any process for extracting moisture that does not also provide for the delivery of a practically constant weight of air to the furnace, will not yield the economy that is now obtained at the Isabella furnace.

Our experience with the use of dry air shows that, even under adverse conditions, great economies are possible. Furnace No. 1 at the Isabella plant has made a large output, and has been banked three times—a process which is always detrimental to economy. At the present time, a large part of the lining has given way at about the middle of the stack for a space 20 ft. high and reaching half way around the jacket. A constant stream of water is required to play on this portion of the jacket, in order to keep the furnace in operation. Yet, having all this to contend with, No. 1 is producing iron under dry-blast with a coke-consumption 340 lb. smaller per ton of pig than its companion furnace, of the same size and supplied with the same ores and fuel, under natural-air blast.

The experience of 18 months with dry-air blast has demonstrated several things:

1. The charges settle more quickly and uniformly after casting than in a furnace blown with natural air.
2. The loss in flue-dust is about 2 per cent. less.
3. The furnace works with greater regularity, and off-grades of iron, which are usually sold at a considerable reduction in price, are seldom made; for dry-air blast maintains the regularity of the grade of output, which, in a merchant-furnace, is a considerable advantage. In the product of a furnace blown with natural air, when the silicon is lowered, the sulphur often is increased to such an extent that the pig must either be remelted, or sold at a material reduction in price. With dry-air blast, we have found that there is rarely an appreciable increase in sulphur corresponding to a material reduction in silicon.

The ability to produce pig-iron according to standard specifications, with increased uniformity of grade and composition, makes this process specially valuable to merchant-furnaces, in the operations of which a considerable profit is habitually sacrificed in the marketing of "off" grades of pig-iron.

From the standpoint of a practical blast-furnace manager, retaining a vivid recollection of the daily whims of that crude yet delicate apparatus, the blast-furnace, I can heartily endorse the views expressed by Dr. Raymond, while accepting with respect and gratitude the theoretical explanations advanced by Prof. Howe, Prof. Richards, and other eminent authorities at home and abroad.

SUBJECT TO REVISION.

[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

Screens for Sizing.

BY ERNEST A. HERSAM, BERKELEY, CAL.

(Bethlehem Meeting, February, 1906.)

ACCURATE ore-sizing with screens is drawing attention to certain details that now, more than ever before, require attention. There are many tests that must be preceded by careful sizing. The assayer often could profit by a more careful selection of screens. In milling, more attention is given the slimes produced. Cement-manufacturers are pulverizing and screening finer than they formerly did, and others are reducing materials to fine sizes at high cost, with screens used to govern the fineness of the pulverized product. Fine screens are expensive, easily injured by mis-use, are carried in stock sparingly by most dealers, and are handled often by those who know little about them except their designated number.

More attention, on the whole, needs be given the actual size of the mesh-openings, and less emphasis placed upon any custom or conventionality in numbering. An effort to classify wire screens, in this respect, leads at once into computations, where one is confronted with details of sizes and standards, of different wires, different gauges, and different customs. There is always uncertainty about the exact working-size of a screen until one gives the matter special attention, and devotes more time to it than its simplicity seems to demand. To know only the number is not sufficient for all uses. Often, in sets, superfluous sizes are used; and sizes are omitted that are of critical importance.

In wire screens, the use of different standard sizes of wire makes important differences in dimensions that must be taken into account. The dealer usually grades screens by the number of openings per linear dimensions, regardless of the size of the openings or of the wire. Certain 100-mesh screens in use are found, by measurement, to be actually coarser than others of 90-mesh, a result which is due, of course, to the use of larger wire in the latter than in the former, while in number, the openings remain correct.

In arranging a graded series of screens, following any mathematical law or the line of any curve, the tables which follow will be found of use. The working-spaces of standard screens of the different sizes can be compared in these tables; and the modulations of these spaces that result from varying the wire to produce a different weight of screen, or a different strength, can be seen and chosen from the many combinations possible.

A system of numbering screens by their space-openings would be most desirable could it become general. Numbering from 1 to 1,000 in thousandths of an inch, as has been adopted by certain English manufacturers, for the measurement of wire, or from 1 to 250 in hundredths of a millimeter, were the metric system to be employed, would have many advantages. It is well, in following one's own purpose, to give to the screens such numbers as design their working-sizes, and to regard them by the dimensions of their spaces. By doing this more generally, a better expression of the actual size of screened material would be had than is now common.

The possibility of classifying materials in currents of water, or of air, at different velocities, makes the use of screens, and, fortunately, the finer ones, often unnecessary. But classification by difference in size alone, with no specific gravity condition to enter, requires actual screening. For this need, there are available, and on the market, punched screens, and wire ones, of various metals, and of standard sizes. The punched screens are used extensively in gold-milling, and are regarded by many as superior to other kinds for this purpose. Such screens are made with punched openings, both round and square; and many are punched with the long and narrow needle slot, cut either along horizontal lines or on a diagonal. Some of the screens are punched with a burr purposely left around the edge of the slots, and others with indented slots.

The thickness of a punched metal usually should be between a half and a quarter of the diameter of the hole; but this requisite varies also with the size, and with the kind and the quality of metal. However desirable extreme thinness of the metal would be, causing screens to work freely in the fine sizes, the strength, notwithstanding, must be maintained, and allowance made for the wear of the sheet-metal. Screens are made thicker, relatively to the size, therefore, as they are made to do finer work, since there must be adequate working-area and strength of screen to support this.

Screens made from drawn wire of different metals are strong. Injury most often comes to these from the displacement of wires; and this quality, with the high first cost, often gives reason for using other kinds. Very fine screens are made, desirably, of wire cloth. For many uses, the wire screen has no satisfactory substitute.

The shape and area of the apertures through which the crushed material must pass is the important quality, if the screen be used for accurate work. Different shapes of screen-openings act differently upon particles of different shapes. Tabular particles can pass the slot screens when they would be held back by square or round openings of equal space; and the passage of needle-like particles must depend, in a measure, upon the kind and violence of the motion and the thickness of the sheet-metal. Different minerals and rocks break into different shapes of particles; and the methods of pulverizing influence this. Abrasion tends to destroy any extreme irregularity of shape, and so, for the most part, crushed substance like ore breaks into particles of no very great disparity of axial dimensions.

If one might neglect these differences in the shape, which result from cleavage and crystallization, and which arise from the different action of the crusher upon particles that are brittle, elastic or malleable, the mean condition of dimensions, or the average shape of particles, would be spherical. This shape cannot be fairly neglected; but in the grading of screens it is well to consider their work as if upon either spherical or cubical particles; and where difference in the shape is taken into consideration, one then may use the sphere or the cube as a basis in making the necessary modification. If uniform rock tends to assume certain forms in the large pieces, it is likely to do this also in the small sizes, and the relation between diameter and mass then holds through all sizes. Ores, however, being composed of mixed minerals, liberate crystals or minerals of different shapes upon crushing, and no relation holds that can be predicted definitely. Allowance usually must be made for the widest difference in size that could be probable among these particles, as they escape from the rough action of the crusher.

This difference will be found greater than is desired, but it must not in any way discourage close work with screens. Brunton[1] finds with a single mineral (pyrite), particles passing the screen which are nearly three times the size (mass) of the theoretical cube that could pass. On the other hand, with a mineral like quartz, pieces commonly are taken from screens which are only one-third and one-fourth the weight of the theoretical cube.

Thus, there is an overlapping in the actual weight of particles from one size of screen to the next, in a closely graded set. This lays emphasis upon the motion that is given the screen to force the ore through, upon the length of time allowed the particles to find a position to pass, and upon the mass of material on the screen obstructing the freedom of motion, with other conditions that modify the mechanical action, all of which, if not made uniform, would have much influence upon the results obtained with screens uniform in size.

In the fine sizes, moisture in the ore has influence. The different frictional resistance of fine particles, too, affects their behavior. Their contacts, with increased surface and smaller masses, influenced by an increase of their appreciable cohesive force, affects them. The diminished force of gravity and momentum acting upon these smaller masses having greater proportionate surfaces, makes the departure from the behavior of the theoretical cube different for different sizes.

The effects of the size of the screen are distinct, however, upon the average size of a product, or upon products typified, in single sizes. Deviations from such a typical condition are characteristic of the ore, and are functions of this, as well as of the size to which the ore is crushed. Screens are gauged as accurately, therefore, as though the products were strictly uniform.

The slot screen, in this regard, has only one dimension to be considered, the width of the slot. The length of the slot is limited chiefly by the strength desired, and for ore-sizing, this length is sufficient to be disregarded. The square-punched or the woven wire screen must be rated according to the space between wires, or the diameter of the largest possible inscribed circle in the rectangular opening. The round-punched screen is measured by the diameter of the openings.

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[1] *Trans.*, xxv., 832.

Also, the thickness of a punched sheet has something to do with the size of the irregularly shaped particles that actually pass; but thickness, necessarily, increases the tendency of a screen to clog, and any difference in size that can arise from difference in thickness, if a screen is suitable to use at all, is small compared with other factors.

Microscopic examination shows that most fine cloth-screens are well made; and that the wire from which they are woven is gauged evenly by some standard intended by the manufacturer. The benefit of this accuracy, however, may not always fall upon the consumer, who finds difficulty, perhaps, in obtaining the exact size desired without delay, or without danger of specifying sizes difficult to produce.

A large number of screens of many kinds have been measured by projecting parallel rays of light through them and through the lenses of a stereopticon to a wall upon which they could be measured. After testing the lens of a stereopticon, measurement can be made conveniently in this way with much accuracy. A large field is exposed to view; and aberration of light is avoided by attaching pieces of the fine screens to ground-glass slides for their projection. Any irregularity is detected at once by the eye, and the finest wire is measured accurately with a drawing-scale.

The result of the examination of these screens shows the need of care by all who are using screens for accurate work. One must be certain not only that the number of apertures per linear inch is correct, but that the size of wire, if uniform, is of the size expected; and one must see what effect this size has upon the diameter of the available aperture.

In the following tables are given the space-openings of screens of different sizes, when made correctly of standard wire. The calculation upon which the tables are based refers to the size of spherical particles which screens would permit to pass. Different standard-gauges are shown, as are required, to cover the needs of the prevailing manufacturing customs.

Whereas, iron or steel usually is measured by the Worcester (Washburn and Moen or the Roebling) gauge, copper is measured by the American (Brown and Sharpe) gauge, and brass wire by the Old English, or London gauge, or by the Birmingham (or Stub's) gauge in the coarser sizes.

The tables can be used to select from the standard sizes, such screens as are required in any graded series. Within a certain limit, it is justifiable to vary the wire in ordering, so as to obtain the exact sizes wanted. For this purpose, screens of different weight, of different sizes of wire, are shown.

The letter *d* represents the screens used by Prof. De Kalb in his tests and graphic records.[2]

The letter *f* shows the screens which most nearly approach a series based upon quarters, eighths and sixteenths of inches, as mentioned below.

The letter *h* represents screen-sizes that correspond to those described by W. S. Hutchinson[3] and used in connection with Prof. Richards' work on Ore Dressing.

The letter *p* shows those sizes that closely approach the space of certain standard needle-slot screens which are made.

The letter *r*, in the reference column, shows sizes closely approaching those used by Rittinger, obtained by the use of a size of wire recommended in a table published by the *School of Mines Quarterly*.[4]

The letter *s* shows sizes used by Brunton in his work upon ore-sampling.[5]

The letter *t* shows the sizes of all those desirable screens, in each table, which approach most nearly the sizes represented in Table I., below.

The tables will be found arranged in the order of decreasing sizes resulting from the use of heavier wire, within limits. Sizes will be found approaching closely any sizes required in a graded series.

A series, to be consistent, often should follow, in geometrical progression, a constant fractional reduction from size to size. Thus, a series of 2, 1, $\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{8}$, $\frac{1}{16}$, $\frac{1}{32}$, $\frac{1}{64}$, $\frac{1}{128}$, $\frac{1}{256}$ and $\frac{1}{512}$ in., or, expressed in decimals, 2, 1, 0.5, 0.25, 0.125, 0.0625,

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[2] *Trans.*, xxviii., 484 (1898).

[3] *Trans.*, xxxv., 258 (1905).

[4] *School of Mines Quarterly*, vol. ii., p. 216 ( ).

[5] *Trans.*, xxv., 827 (1895).

0.0312, 0.0156, 0.0078, 0.0039 and 0.0020 in., is satisfactory for general use. The nearest approach to such a series of screens as this, is shown by the letter *f* in the tables.

A desirable graded series of screens is shown by the space openings represented in Table I. These follow the lines of such a curve as has been used by Rittinger, and they are extended in the tabulation, here, in order to cover the extremely fine sizes. The nearest approach to these desirable space openings, that can be obtained by the use of standard wire, is here represented by the mesh of the screen and the number of the wire.

TABLE I.—*A Graded Series of Screens.*

Openings Desired.		Meshes* to the Inch.	Size of Brass Wire. Old English or London Gauge.	Openings Desired.		Meshes to the Inch.	Size of Brass Wire. Old English or London Gauge.
Millimeters.	Inches.			Millimeters.	Inches.		
64.0	2.56	3″	000	0.50	0.020	26	27
45.2	1.80	2⅛″	0			28	29
32.0	1.28	1½″	3			30	30
22.6	0.890	1⅛″	4			35	35
16.0	0.630	¾″	11	0.35	0.014	35	30
11.3	0.445	⅝″	7			40	32
8.0	0.315	2½	14			50	38
5.6	0.222	3½	16	0.25	0.0098	50	34
4.0	0.157	4	13			55	35
		4½	16	0.175	0.0069	74	37
		5	19			80	38
2.8	0.111	7	21	0.125	0.0049	90	38
2.0	0.079	7	16			100	39
		9	21			120	43
1.41	0.056	12	23	0.087	0.0034	150	44
		14	29			160	45
1.00	0.039	16	25	0.062	0.0024	160	43
		18	28			180	44
		20	32			190	45
		22	36			200	45½
0.70	0.028	18	23	0.043	0.0017	180	43
		20	25			190	43
		22	26			200	44
		24	30	0.031	0.0012	190	42
		26	33	0.022	0.0009	200	42

* Where the sign of inches (″) is expressed, the number signifies "inches to the mesh."

The needle-slot screens do not conform with screens of wire-cloth in their designated number. In punched screens, the size of the opening is incidental to nothing else. Coarse sizes can be obtained of any space opening desired in simple fractions of inches or millimeters. Certain finer sizes, which are represented by smaller fractions, are shown in Table II.

TABLE II.—*Openings in Certain Punched Screens.*

No.	Mesh.	Width of Slot.		No.	Mesh.	Width of Slot.	
		Inches.	Millimeters.			Inches.	Millimeters.
1	12	0.058	1.47	8	35	0.022	0.56
2	14	0.049	1.24	9	40	0.020	0.51
3	16	0.042	1.07	10	50	0.018	0.46
4	18	0.035	0.89	11	55	0.0165	0.42
5	20	0.029	0.74	12	60	0.015	0.38
6	25	0.027	0.69	13	70	0.0135	0.34
7	30	0.024	0.61				

In Tables III. to VI., inclusive, the following references are used:—

d. Represents the size of screens used by De Kalb.[6]

f. Represents the nearest approach to sizes of a set graded as follows:—1″, ½″, ¼″, etc. (see p. 406).

h. Shows screens which have been used by Richards as described by Hutchinson.[7]

p. Represents sizes corresponding most nearly to the punched screens given in Table II.

s. Represents the screens used by Brunton.[8]

t. Represents all sizes shown in Table I.

r. Shows Rittinger screens, elsewhere advised.[9]

In the column representing the screen numbers, when the sign of inches (″) is expressed, the number is understood to imply "inches to the mesh." When no sign of inches is shown, the number signifies the number of "meshes to the inch." Thus, a ¾″ screen is also a 1⅓ mesh screen. Mesh-dimensions, in all cases, are represented as distances between wire-centers. The working size of screens, or the opening, or aperture, is the clear "space" between wires.

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[6] *Trans.*, xxviii., 484. [7] *Trans.*, xxxv., 258. [8] *Trans.*, xxv., 832.

[9] *School of Mines Quarterly*, vol. ii., p. 216.

TABLE III.—*Sizes of Wire Screens (usually iron or steel) of the Worcester (Washburn & Moen) (Roebling) Standard.*

Mesh.	Wire.		Space.		Reference.
	W. & M.	Diameter in Inches.	Inches.	Milli-meters.	
Inches to the mesh.					
3″	0	0.307	2.69	68.3	
3″	00	0.331	2.67	67.8	r
3″	000	0.362	2.64	67.1	t
2½″	1	0.283	2.22	56.4	
2½″	0	0.307	2.19	55.6	
2½″	00	0.331	2.17	55.1	f
2⅛″	0	0.307	1.82	46.2	rt
1½″	3	0.244	1.26	32.0	t
1½″	2	0.263	1.24	31.5	r
1½″	1	0.283	1.22	31.0	
1⅛″	4	0.225	0.900	22.9	rtf
13/16″	7	0.177	0.635	16.1	r
1″	15	0.072	0.928	23.6	
1″	14	0.080	0.920	23.4	
1″	13	0.092	0.908	23.1	
1″	12	0.105	0.895	22.7	
1″	11	0.120	0.880	22.3	
1″	10	0.135	0.865	22.0	
1″	9	0.148	0.852	21.6	
1″	8	0.162	0.838	21.3	
1″	7	0.177	0.823	20.9	
1″	6	0.192	0.808	20.5	
1″	5	0.207	0.793	20.1	
1″	4	0.225	0.775	19.7	
1″	3	0.244	0.756	19.2	s
¾″	16	0.063	0.687	17.4	
¾″	15	0.072	0.678	17.2	
¾″	14	0.080	0.670	17.0	
¾″	13	0.092	0.658	16.7	
¾″	12	0.105	0.645	16.4	
¾″	11	0.120	0.630	16.0	t
¾″	10	0.135	0.615	15.6	
¾″	9	0.148	0.602	15.3	
¾″	8	0.162	0.588	14.9	
¾″	7	0.177	0.573	14.5	
¾″	6	0.192	0.558	14.2	
¾″	5	0.207	0.543	13.8	
¾″	4	0.225	0.525	13.3	
⅝″	17	0.054	0.571	14.5	
⅝″	16	0.063	0.562	14.3	
⅝″	15	0.072	0.553	14.0	
⅝″	14	0.080	0.545	13.8	
⅝″	13	0.092	0.533	13.5	
⅝″	12	0.105	0.520	13.2	
⅝″	11	0.120	0.505	12.8	f
⅝″	10	0.135	0.490	12.4	
⅝″	9	0.148	0.477	12.1	
⅝″	8	0.162	0.463	11.8	r
⅝″	7	0.177	0.448	11.4	t
⅝″	6	0.192	0.433	11.0	
⅝″	5	0.207	0.418	10.6	
Meshes to the inch.					
2	18	0.047	0.453	11.5	
2	17	0.054	0.446	11.3	
2	16	0.063	0.437	11.1	
2	15	0.072	0.428	10.9	
2	14	0.080	0.420	10.7	
2	13	0.092	0.408	10.4	
2	12	0.105	0.395	10.0	
2	11	0.120	0.380	9.65	
2	10	0.135	0.365	9.27	
2	9	0.148	0.352	8.94	
2	8	0.162	0.338	8.59	s
2	7	0.177	0.323	8.20	
2	6	0.192	0.308	7.82	
2½	19	0.041	0.359	9.12	
2½	18	0.047	0.353	8.97	
2½	17	0.054	0.346	8.79	
2½	16	0.063	0.337	8.56	
2½	15	0.072	0.328	8.33	
2½	14	0.080	0.320	8.13	t
2½	13	0.092	0.308	7.82	
2½	12	0.105	0.295	7.49	r

Mesh.	Wire.		Space.		Reference.
	W. & M.	Diameter in Inches.	Inches.	Milli-meters.	
Meshes to the inch.					
2½	11	0.120	0.280	7.11	
2½	10	0.135	0.265	6.73	
2½	9	0.148	0.252	6.40	
2½	8	0.162	0.238	6.05	
3	20	0.035	0.298	7.57	
3	19	0.041	0.292	7.42	
3	18	0.047	0.286	7.26	
3	17	0.054	0.279	7.09	
3	16	0.063	0.270	6.86	
3	15	0.072	0.261	6.63	
3	14	0.080	0.253	6.43	f
3	13	0.092	0.242	6.15	
3	12	0.105	0.228	5.79	
3	11	0.120	0.213	5.41	
3	10	0.135	0.198	5.03	s
3½	21	0.032	0.253	6.43	
3½	20	0.035	0.250	6.35	
3½	19	0.041	0.244	6.20	
3½	18	0.047	0.238	6.05	
3½	17	0.054	0.231	5.87	
3½	16	0.063	0.222	5.64	t
3½	15	0.072	0.213	5.41	
3½	14	0.080	0.205	5.21	r
3½	13	0.092	0.193	4.90	
3½	12	0.105	0.180	4.57	
3½	11	0.120	0.165	4.19	
4	22	0.028	0.222	5.64	
4	21	0.032	0.218	5.54	
4	20	0.035	0.215	5.46	
4	19	0.041	0.209	5.31	
4	18	0.047	0.203	5.16	
4	17	9.054	0.196	4.98	
4	16	0.063	0.187	4.75	
4	15	0.072	0.178	4.52	
4	14	0.080	0.170	4.32	
4	13	0.092	0.158	4.01	t
4	12	0.105	0.145	3.68	s
4	11	0.120	0.130	3.30	
4½	20	0.035	0.187	4.75	
4½	19	0.041	0.181	4.60	
4½	18	0.047	0.175	4.45	
4½	17	0.054	0.168	4.27	
4½	16	0.063	0.159	4.04	
4½	15	0.072	0.150	3.81	r
4½	14	0.080	0.142	3.61	
4½	13	0.092	0.130	3.30	
4½	12	0.105	0.117	2.97	
5	23	0.025	0.175	4.44	
5	22	0.028	0.172	4.37	
5	21	0.032	0.168	4.27	
5	20	0.035	0.165	4.19	
5	19	0.041	0.159	4.04	
5	18	0.047	0.153	3.89	
5	17	0.054	0.146	3.71	
5	16	0.063	0.137	3.48	
5	15	0.072	0.128	3.25	
5	14	0.080	0.120	3.05	
5	13	0.092	0.108	2.74	s
6	24	0.023	0.144	3.66	
6	23	0.025	0.142	3.61	
6	22	0.028	0.139	3.53	
6	21	0.032	0.135	3.43	
6	20	0.035	0.132	3.35	
6	19	0.041	0.126	3.20	f
6	18	0.047	0.120	3.05	
6	17	0.054	0.113	2.87	
6	16	0.063	0.104	2.64	r
6	15	0.072	0.095	2.40	
6	14	0.080	0.087	2.20	s
7	26	0.018	0.125	3.17	
7	25	0.020	0.123	3.12	
7	24	0.023	0.120	3.05	

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f. Nearest approach to sizes of graded set, 1″, ½″, ¼″, etc. *p*. Nearest size to punched screens, Table II. *s*, Brunton's screens. *t*. Sizes in Table I. *r*. Rittinger's screens,

TABLE III.—*Continued.*

Meshes to the inch.

Mesh.	Wire.		Space.		Reference.
	W. & M.	Diameter in Inches.	Inches.	Millimeters.	
7	23	0.025	0.118	3.00	
7	22	0.028	0.115	2.92	
7	21	0.032	0.111	2.82	t
7	20	0.035	0.108	2.74	
7	19	0.041	0.102	2.59	
7	18	0.047	0.096	2.44	
7	17	0.054	0.089	2.26	
7	16	0.063	0.080	2.03	
7	15	0.072	0.071	1.80	s
8	27	0.017	0.108	2.74	
8	26	0.018	0.107	2.72	
8	25	0.020	0.105	2.67	
8	24	0.023	0.102	2.59	
8	23	0.025	0.100	2.54	
8	22	0.028	0.097	2.46	
8	21	0.032	0.093	2.36	
8	20	0.035	0.090	2.29	
8	19	0.041	0.084	2.13	
8	18	0.047	0.078	1.98	r
8	17	0.054	0.071	1.80	
8	16	0.063	0.062	1.57	s
9	28	0.016	0.095	2.42	
9	27	0.017	0.094	2.39	
9	26	0.018	0.093	2.36	
9	25	0.020	0.091	2.31	
9	24	0.023	0.088	2.24	
9	23	0.025	0.086	2.19	
9	22	0.028	0.083	2.11	
9	21	0.032	0.079	2.01	t
9	20	0.035	0.076	1.93	
9	19	0.041	0.070	1.78	
9	18	0.047	0.064	1.63	
9	17	0.054	0.057	1.45	s
10	29	0.015	0.085	2.17	
10	28	0.016	0.084	2.13	
10	27	0.017	0.083	2.11	
10	26	0.018	0.082	2.08	
10	25	0.020	0.080	2.03	
10	24	0.023	0.077	1.96	
10	23	0.025	0.075	1.90	
10	22	0.028	0.072	1.83	
10	21	0.032	0.068	1.73	
10	20	0.035	0.065	1.65	
10	19	0.041	0.059	1.50	
10	18	0.047	0.053	1.35	s
10	17	0.054	0.046	1.17	
12	30	0.014	0.069	1.75	
12	29	0.015	0.068	1.73	
12	28	0.016	0.067	1.70	
12	27	0.017	0.066	1.68	
12	26	0.018	0.065	1.65	
12	25	0.020	0.063	1.60	f
12	24	0.023	0.060	1.52	
12	23	0.025	0.058	1.47	p
12	22	0.028	0.055	1.40	rt
12	21	0.032	0.051	1.30	
12	20	0.035	0.048	1.22	
12	19	0.041	0.042	1.07	s
14	34	0.010	0.061	1.56	
14	33	0.011	0.060	1.53	
14	32	0.013	0.059	1.48	
14	31	0.0135	0.058	1.47	
14	30	0.014	0.057	1.46	
14	29	0.015	0.056	1.43	
14	28	0.016	0.055	1.41	
14	27	0.017	0.054	1.38	
14	26	0.018	0.053	1.36	
14	25	0.020	0.051	1.31	
14	24	0.023	0.048	1.23	p
14	23	0.025	0.046	1.18	
14	22	0.028	0.043	1.10	
14	21	0.032	0.039	1.00	
14	20	0.035	0.036	0.92	s
16	35	0.0095	0.053	1.35	
16	34	0.010	0.052	1.33	
16	33	0.011	0.051	1.31	
16	32	0.013	0.050	1.26	
16	31	0.0135	0.049	1.24	
16	30	0.014	0.048	1.23	
16	29	0.015	0.047	1.21	
16	28	0.016	0.046	1.18	
16	27	0.017	0.045	1.16	
16	26	0.018	0.044	1.13	
16	25	0.020	0.042	1.08	pr
16	24	0.023	0.039	1.00	
16	23	0.025	0.037	0.95	
16	22	0.028	0.034	0.88	s
16	21	0.032	0.030	0.77	
18	36	0.009	0.047	1.18	
18	35	0.0095	0.046	1.17	
18	34	0.010	0.045	1.16	
18	33	0.011	0.044	1.13	
18	32	0.013	0.043	1.08	
18	31	0.0135	0.042	1.07	
18	30	0.014	0.041	1.05	
18	29	0.015	0.040	1.03	
18	28	0.016	0.039	1.00	t
18	27	0.017	0.038	0.98	
18	26	0.018	0.037	0.95	
18	25	0.020	0.035	0.90	p
18	24	0.023	0.032	0.82	
18	23	0.025	0.030	0.77	s
18	22	0.028	0.027	0.69	
20	35	0.0095	0.041	1.03	
20	34	0.010	0.040	1.02	
20	33	0.011	0.039	0.99	
20	32	0.013	0.038	0.94	
20	31	0.0135	0.037	0.93	
20	30	0.014	0.036	0.91	
20	29	0.015	0.035	0.89	
20	28	0.016	0.034	0.86	
20	27	0.017	0.033	0.84	
20	26	0.018	0.032	0.81	
20	25	0.020	0.030	0.76	p
20	24	0.023	0.027	0.69	s
20	23	0.025	0.025	0.63	
22	35	0.0095	0.038	0.96	
22	34	0.010	0.037	0.94	
22	33	0.011	0.036	0.92	
22	32	0.013	0.035	0.87	
22	31	0.0135	0.034	0.86	
22	30	0.014	0.033	0.84	
22	29	0.015	0.032	0.82	
22	28	0.016	0.031	0.79	f
22	27	0.017	0.030	0.77	
22	26	0.018	0.029	0.74	
22	25	0.020	0.027	0.69	
22	24	0.023	0.024	0.61	s
24	36	0.009	0.033	0.83	
24	35	0.0095	0.032	0.82	
24	34	0.010	0.031	0.80	
24	33	0.011	0.030	0.78	
24	32	0.013	0.029	0.73	
24	31	0.0135	0.028	0.71	
24	30	0.014	0.027	0.70	t
24	29	0.015	0.026	0.68	p
24	28	0.016	0.025	0.65	r
24	27	0.017	0.024	0.62	
24	26	0.018	0.023	0.60	s
24	25	0.020	0.022	0.55	
26	36	0.009	0.030	0.75	
26	35	0.0095	0.029	0.73	
26	34	0.010	0.028	0.72	
26	33	0.011	0.027	0.70	

f. Nearest approach to sizes of graded set, 1″, ½″, ¼″, etc. *p.* Nearest size to punched screens, Table II. *s.* Brunton's screens. *t.* Sizes in Table I. *r,* Rittinger's screens.

TABLE III.—*Concluded.*

Mesh. Meshes to the inch.	Wire.		Space.		Reference.	Mesh. Meshes to the inch.	Wire.		Space.		Reference.
	W. & M.	Diameter in Inches.	Inches.	Milli-meters.			W. & M.	Diameter in Inches.	Inches.	Milli-meters.	
26	32	0.013	0.026	0.64		50	37	0.0085	0.0115	0.29	
26	31	0.0135	0.025	0.63		50	36	0.009	0.011	0.28	
26	30	0.014	0.024	0.62	p	50	35	0.0095	0.0105	0.27	s
26	29	0.015	0.023	0.59		50	34	0.010	0.010	0.25	rt
26	28	0.016	0.022	0.57		50	33	0.011	0.009	0.23	
26	27	0.017	0.021	0.54		50	32	0.013	0.007	0.18	
26	26	0.018	0.020	0.52		55	38	0.008	0.010	0.25	
28	36	0.009	0.027	0.68		55	37	0.0085	0.0095	0.24	
28	35	0.0095	0.026	0.67		55	36	0.009	0.009	0.23	
28	34	0.010	0.025	0.65		55	35	0.0095	0.0085	0.22	
28	33	0.011	0.024	0.63		55	34	0.010	0.008	0.20	
28	32	0.013	0.023	0.58		60	39	0.0075	0.009	0.23	
28	31	0.0135	0.022	0.56		60	38	0.008	0.0085	0.22	
28	30	0.014	0.021	0.55		60	37	0.0085	0.008	0.20	f
28	29	0.015	0.020	0.53		60	36	0.009	0.0075	0.19	
28	28	0.016	0.019	0.50		60	35	0.0095	0.007	0.18	
30	35	0.0095	0.024	0.60		64	40	0.007	0.0085	0.22	
30	34	0.010	0.023	0.59		64	39	0.0075	0.008	0.20	
30	33	0.011	0.022	0.57	p	64	38	0.008	0.0075	0.19	
30	32	0.013	0.021	0.52		64	37	0.0085	0.007	0.18	
30	31	0.0135	0.020	0.50	pt	64	36	0.009	0.0065	0.17	
30	30	0.014	0.019	0.49		70	40	0.007	0.007	0.18	
30	29	0.015	0.018	0.46		70	39	0.0075	0.0065	0.17	t
30	28	0.016	0.017	0.44	s	70	38	0.008	0.006	0.15	r
30	27	0.017	0.016	0.41		70	37	0.0085	0.0055	0.14	
35	36	0.009	0.020	0.50		70	36	0.009	0.005	0.13	
35	35	0.0095	0.019	0.48		74	41	0.0066	0.007	0.18	
35	34	0.010	0.018	0.47	p	74	40	0.0070	0.0065	0.17	
35	33	0.011	0.017	0.44		74	39	0.0075	0.006	0.15	
35	32	0.013	0.016	0.39	f	74	38	0.0080	0.0055	0.14	
35	31	0.0135	0.015	0.38	r	74	37	0.0085	0.005	0.13	
35	30	0.014	0.014	0.37		80	42	0.0062	0.0065	0.16	
35	29	0.015	0.013	0.34		80	41	0.0066	0.006	0.15	
40	37	0.0085	0.0165	0.42	p	80	40	0.0070	0.0055	0.14	
40	36	0.009	0.016	0.41		80	39	0.0075	0.005	0.13	t
40	35	0.0095	0.0155	0.39		80	38	0.0080	0.0045	0.11	
40	34	0.010	0.015	0.38	p	80	37	0.0085	0.004	0.10	
40	33	0.011	0.014	0.36	pt	90	42	0.0062	0.005	0.12	
40	32	0.013	0.012	0.30	s	90	41	0.0066	0.0045	0.11	
40	31	0.0135	0.0115	0.29		90	40	0.0070	0.004	0.10	f
40	30	0.014	0.011	0.28		90	39	0.0075	0.0035	0.09	
45	37	0.0085	0.014	0.35		90	38	0.0080	0.003	0.08	
45	36	0.009	0.013	0.33		100	42	0.0062	0.004	0.10	
45	35	0.0095	0.0125	0.32		100	41	0.0066	0.0035	0.09	t
45	34	0.010	0.012	0.30		100	40	0.0070	0.003	0.08	
45	33	0.011	0.011	0.28		100	39	0.0075	0.0025	0.06	t
45	32	0.013	0.009	0.23							

f. Nearest approach to sizes of graded set, 1″, ½″, ¼″, etc. *p.* Nearest size to punched screens, Table II. *s.* Brunton's screens. *t.* Sizes in Table I. *r.* Rittinger's screens.

TABLE IV.—*Sizes of Wire Screens (usually brass) of the Old English or London Gauge.*

	Mesh.	Wire.		Space.		Reference.		Mesh.	Wire.		Space.		Reference.
		Old English.	Diameter in Inches.	Inches.	Milli-meters.				Old English.	Diameter in Inches.	Inches.	Milli-meters.	
Inches to the mesh.	3″	0	0.340	2.66	67.6		Meshes to the inch.	3	20	0.035	0.298	7.57	
	3″	00	0.380	2.62	66.5	r		3	19	0.040	0.293	7.44	
	3″	000	0.425	2.57	65.3	t		3	18	0.049	0.284	7.21	
	2½″	1	0.300	2.20	50.8			3	17	0.058	0.275	6.98	
	2½″	0	0.340	2.16	54.9			3	16	0.065	0.268	6.81	
	2½″	00	0.380	2.12	53.8	f		3	15	0.072	0.261	6.63	
	2⅛″	0	0.340	1.78	45.2	rt		3	14	0.083	0.250	6.35	f
	1½″	3	0.259	1.24	31.5	rt		3	13	0.095	0.238	6.05	
	1½″	2	0.284	1.22	31.0	r		3	12	0.109	0.224	5.69	
	1½″	1	0.300	1.20	30.5			3	11	0.120	0.213	5.41	
	1⅛″	4	0.238	0.89	22.8	rt		3	10	0.134	0.199	5.05	
	1″	15	0.072	0.938	23.8	f		3½	20	0.035	0.250	6.35	
	1″	14	0.083	0.917	23.3			3½	19	0.040	0.245	6.22	
	1″	13	0.095	0.905	23.0			3½	18	0.049	0.236	5.99	
	1″	12	0.109	0.891	22.6	d		3½	17	0.058	0.227	5.77	
	1″	11	0.120	0.880	22.3			3½	16	0.065	0.220	5.59	t
	1″	10	0.134	0.866	22.0			3½	15	0.072	0.213	5.41	
	1″	9	0.148	0.852	21.6			3½	14	0.083	0.202	5.13	r
	1″	8	0.165	0.835	21.2			3½	13	0.095	0.190	4.83	
	1″	7	0.180	0.820	20.8			3½	12	0.109	0.176	4.47	
	1″	6	0.203	0.797	20.2			3½	11	0.120	0.165	4.19	
	1″	5	0.220	0.780	19.8			4	21	0.0315	0.218	5.54	
	1″	4	0.238	0.762	19.3			4	20	0.035	0.215	5.46	
	1″	3	0.259	0.741	18.8			4	19	0.040	0.210	5.33	
	¾″	16	0.065	0.685	17.4			4	18	0.049	0.201	5.11	d
	¾″	15	0.072	0.678	17.2			4	17	0.058	0.192	4.88	
	¾″	14	0.083	0.667	16.9			4	16	0.065	0.185	4.70	
	¾″	13	0.095	0.655	16.6	d		4	15	0.072	0.178	4.52	
	¾″	12	0.109	0.641	16.3			4	14	0.083	0.167	4.24	
	¾″	11	0.120	0.630	16.0	t		4	13	0.095	0.155	3.94	t
	¾″	10	0.134	0.616	15.6			4	12	0.109	0.141	3.58	
	¾″	9	0.148	0.602	15.3			4	11	0.120	0.130	3.30	
	¾″	8	0.165	0.585	14.9			4½	21	0.0315	0.191	4.85	
	¾″	7	0.180	0.570	14.5			4½	20	0.035	0.187	4.75	
	¾″	6	0.203	0.547	13.9			4½	19	0.040	0.182	4.62	
	¾″	5	0.220	0.530	13.5			4½	18	0.049	0.173	4.39	
	¾″	4	0.238	0.512	13.0			4½	17	0.058	0.164	4.17	
	⅝″	17	0.058	0.567	14.4			4½	16	0.065	0.157	3.99	
	⅝″	16	0.065	0.560	14.2			4½	15	0.072	0.150	3.81	r
	⅝″	15	0.072	0.553	14.1			4½	14	0.083	0.139	3.53	
	⅝″	14	0.083	0.542	13.8			4½	13	0.095	0.127	3.23	
	⅝″	13	0.095	0.530	13.5			4½	12	0.109	0.113	2.87	
	⅝″	12	0.109	0.516	13.1			5	24	0.025	0.175	4.44	
	⅝″	11	0.120	0.505	12.8	f		5	23	0.027	0.173	4.39	
	⅝″	10	0.134	0.491	12.5			5	22	0.0295	0.170	4.32	
	⅝″	9	0.148	0.477	12.1			5	21	0.0315	0.168	4.27	
	⅝″	8	0.165	0.460	11.7	r		5	20	0.035	0.165	4.19	
	⅝″	7	0.180	0.445	11.3	t		5	19	0.040	0.160	4.06	
	⅝″	6	0.203	0.422	10.7			5	18	0.049	0.151	3.84	
	⅝″	5	0.220	0.405	10.3			5	17	0.058	0.142	3.61	
Meshes to the inch.	2	18	0.049	0.451	11.46			5	16	0.065	0.135	3.43	
	2	17	0.058	0.442	11.23			5	15	0.072	0.128	3.25	
	2	16	0.065	0.435	11.05	d		5	14	0.083	0.117	2.97	
	2	15	0.072	0.428	10.87			5	13	0.095	0.105	2.67	
	2	14	0.083	0.417	10.59			6	25	0.023	0.143	3.63	
	2	13	0.095	0.405	10.29			6	24	0.025	0.141	3.58	
	2	12	0.109	0.391	9.93			6	23	0.027	0.139	3.53	
	2	11	0.120	0.380	9.65			6	22	0.0295	0.137	3.48	
	2	10	0.134	0.366	9.30			6	21	0.0315	0.135	3.43	
	2	9	0.148	0.352	8.94			6	20	0.035	0.131	3.33	
	2	8	0.165	0.335	8.51			6	19	0.040	0.126	3.20	
	2½	19	0.040	0.360	9.14			6	18	0.049	0.117	2.97	
	2½	18	0.049	0.351	8.92			6	17	0.058	0.108	2.74	
	2½	17	0.058	0.342	8.69			6	16	0.065	0·101	2.57	r
	2½	16	0.065	0.335	8.51			6	15	0.072	0.094	2.39	
	2½	15	0.072	0.328	8.33			6	14	0.083	0.083	2.11	
	2½	14	0.083	0.317	8.05	t		7	26	0.0205	0.122	3.10	
	2½	13	0.095	0.305	7.75			7	25	0.023	0.120	3.05	
	2½	12	0.109	0.291	7.39	r		7	24	0.025	0.118	3.00	
	2½	11	0.120	0.280	7.11			7	23	0.027	0.116	2.95	
	2½	10	0.134	0.266	6.76			7	22	0.0295	0.113	2.87	
	2½	9	0.148	0.252	6.40			7	21	0.0315	0.111	2.82	t

d. de Kalb screens. *f.* Nearest approach to sizes of graded set, 1″, ½″, ¼″, etc. *h.* Richards (Hutchinson) screens. *p.* Nearest size to punched screens, Table II. *s.* Brunton's screens *t.* Sizes in Table I. *r.* Rittinger's screens.

TABLE IV.—*Continued.*

Mesh. Meshes to the inch.	Wire. Old English.	Wire. Diameter in Inches.	Space. Inches.	Space. Millimeters.	Reference.
7	20	0.035	0.108	2.74	
7	19	0.040	0.103	2.62	
7	18	0.049	0.094	2.39	
7	17	0.058	0.085	2.16	
7	16	0.065	0.078	1.98	
7	15	0.072	0.071	1.80	
8	27	0.0187	0.106	2.69	
8	26	0.0205	0.104	2.64	
8	25	0.023	0.102	2.59	
8	24	0.025	0.100	2.54	
8	23	0.027	0.098	2.49	
8	22	0.0295	0.095	2.41	d
8	21	0.0315	0.093	2.36	
8	20	0.035	0.090	2.29	
8	19	0.040	0.085	2.16	
8	18	0.049	0.076	1.93	r
8	17	0.058	0.067	1.70	
8	16	0.065	0.060	1.52	
9	28	0.0165	0.095	2.40	
9	27	0.0187	0.092	2.35	
6	26	0.0205	0.091	2.30	
6	25	0.023	0.088	2.24	
9	24	0.025	0.086	2.19	
9	23	0.027	0.084	2.14	
9	22	0.0295	0.082	2.07	
9	21	0.0315	0.080	2.02	t
9	20	0.035	0.076	1.93	
9	19	0.040	0.071	1.81	
9	18	0.049	0.062	1.57	f
9	17	0.058	0.053	1.35	
10	29	0.0155	0.084	2.13	
10	28	0.0165	0.083	2.11	
10	27	0.0187	0.081	2.06	
10	26	0.0205	0.079	2.00	
10	25	0.023	0.077	1.96	
10	24	0.025	0.075	1.90	
10	23	0.027	0.073	1.85	d
10	22	0.0295	0.070	1.78	
10	21	0.0315	0.068	1.73	
10	20	0.035	0.065	1.65	
10	19	0.040	0.060	1.52	
10	18	0.049	0.051	1.29	
12	30	0.0137	0.070	1.78	
12	29	0.0155	0.068	1.73	
12	28	0.0165	0.067	1.70	
12	27	0.0187	0.065	1.65	
12	26	0.0205	0.063	1.60	
12	25	0.023	0.060	1.52	
12	24	0.025	0.058	1.47	pd
12	23	0.027	0.056	1.42	t
12	22	0.0295	0.054	1.37	r
12	21	0.0315	0.052	1.32	
12	20	0.035	0.048	1.22	
12	19	0.040	0.043	1.09	
14	34	0.0095	0.062	1.57	
14	33	0.0102	0.061	1.55	
14	32	0.0112	0.060	1.52	
14	31	0.0122	0.059	1.50	
14	30	0.0137	0.058	1.47	
14	29	0.0155	0.056	1.42	
14	28	0.0165	0.055	1.40	
14	27	0.0187	0.053	1.35	
14	26	0.0205	0.051	1.30	
14	25	0.0230	0.048	1.22	
14	24	0.0250	0.046	1.17	
14	23	0.0270	0.044	1.12	
14	22	0.0295	0.042	1.07	
14	21	0.0315	0.040	1.02	
14	20	0.0350	0.036	0.91	
16	35	0.0090	0.053	1.36	
16	34	0.0095	0.053	1.35	
16	33	0.0102	0.051	1.30	
16	32	0.0112	0.050	1.27	
16	31	0.0122	0.049	1.25	
16	30	0.0137	0.049	1.24	p
16	29	0.0155	0.047	1.19	
16	28	0.0165	0.046	1.17	
16	27	0.0187	0.044	1.12	
16	26	0.0205	0.042	1.07	d
16	25	0.0230	0.039	0.99	rt
16	24	0.0250	0.037	0.94	
16	23	0.0270	0.035	0.89	
16	22	0.0295	0.033	0.84	
16	21	0.0315	0.031	0.79	
18	36	0.0075	0.048	1.22	
18	35	0.0090	0.046	1.18	
18	34	0.0095	0.046	1.17	
18	33	0.0102	0.045	1.14	
18	32	0.0112	0.044	1.12	
18	31	0.0122	0.043	1.09	
18	30	0.0137	0.042	1.07	p
18	29	0.0155	0.040	1.04	
18	28	0.0165	0.039	0.99	
18	27	0.0187	0.037	0.84	
18	26	0.0205	0.035	0.89	
18	25	0.0230	0.032	0.81	
18	24	0.0250	0.030	0.76	
18	23	0.0270	0.028	0.71	
18	22	0.0295	0.026	0.66	
20	36	0.0075	0.042	1.07	
20	35	0.0090	0.041	1.04	
20	34	0.0095	0.040	1.02	
20	33	0.0102	0.040	1.01	
20	32	0.0112	0.039	0.99	
20	31	0.0122	0.038	0.97	
20	30	0.0137	0.036	0.91	
20	29	0.0155	0.034	0.86	
20	28	0.0165	0.033	0.84	d
20	27	0.0187	0.031	0.79	f
20	26	0.0205	0.029	0.74	
20	25	0.0230	0.027	0.69	
20	24	0.0250	0.025	0.63	
20	23	0.0270	0.023	0.58	
20	22	0.0295	0.020	0.51	
20	21	0.0315	0.019	0.48	
20	20	0.0350	0.015	0.38	
22	36	0.0075	0.039	1.01	
22	35	0.0090	0.038	0.97	
22	34	0.0095	0.038	0.95	
22	33	0.0102	0.037	0.94	
22	32	0.0112	0.036	0.91	
22	31	0.0122	0.035	0.89	p
22	30	0.0137	0.033	0.84	
22	29	0.0155	0.032	0.80	
22	28	0.0165	0.031	0.78	
22	27	0.0187	0.028	0.71	
22	26	0.0205	0.027	0.69	
22	25	0.0230	0.024	0.61	
22	24	0.0250	0.022	0.56	
24	36	0.0075	0.034	0.86	
24	35	0.0090	0.033	0.83	
24	34	0.0095	0.032	0.81	
24	33	0.0102	0.030	0.76	
24	32	0.0112	0.029	0.74	p
24	31	0.0122	0.028	0.72	
24	30	0.0137	0.028	0.71	td
24	29	0.0155	0.026	0.66	
24	28	0.0165	0.025	0.63	r
24	27	0.0187	0.023	0.58	
24	26	0.0205	0.021	0.53	
24	25	0.0230	0.019	0.48	
26	36	0.0075	0.031	0.79	
26	35	0.0090	0.029	0.75	
26	34	0.0095	0.029	0.74	

d. De Kalb screens. *f*. Nearest approach to sizes of graded set, 1″ ½″, ¼″, etc. *h*. Richards (Hutchinson) screens. *p*. Nearest size to punched screens, Table II. *s*. Brunton's screens. *t*. Sizes in Table I. *r*. Rittinger's screens.

TABLE IV.—*Concluded.*

Meshes to the inch.

Mesh.	Wire.		Space.		Reference.
	Old English.	Diameter in Inches.	Inches.	Millimeters.	
26	33	0.0102	0.028	0.71	
26	32	0.0112	0.027	0.69	p
26	31	0.0122	0.026	0.66	
26	30	0.0137	0.025	0.63	
26	29	0.0155	0.023	0.58	
26	28	0.0165	0.022	0.56	
26	27	0.0187	0.020	0.51	
26	26	0.0205	0.018	0.46	
28	36	0.0075	0.028	0.71	
28	35	0.0090	0.028	0.70	
28	34	0.0095	0.026	0.66	
28	33	0.0102	0.025	0.63	
28	32	0.0112	0.024	0.61	p
28	31	0.0122	0.023	0.58	
28	30	0.0137	0.022	0.56	
28	29	0.0155	0.020	0.51	
28	28	0.0165	0.019	0.48	
30	36	0.0075	0.026	0.65	
30	35	0.0090	0.024	0.61	
30	34	0.0095	0.024	0.60	
30	33	0.0102	0.023	0.58	
30	32	0.0112	0.022	0.56	p
30	31	0.0122	0.021	0.53	d
30	30	0.0137	0.020	0.50	tp
30	29	0.0155	0.018	0.46	
30	28	0.0165	0.017	0.43	
35	36	0.0075	0.021	0.53	
35	35	0.0090	0.019	0.50	
35	34	0.0095	0.019	0.48	
35	33	0.0102	0.018	0.46	p
35	32	0.0112	0.017	0.43	
35	31	0.0122	0.016	0.41	rp
35	30	0.0137	0.014	0.35	
35	29	0.0155	0.013	0.33	
40	36	0.0075	0.017	0.44	
40	35	0.0090	0.016	0.41	
40	34	0.0095	0.015	0.39	p
40	33	0.0102	0.015	0.37	fdh
40	32	0.0112	0.014	0.35	t
40	31	0.0122	0.013	0.32	
40	30	0.0137	0.011	0.28	
45	36	0.0075	0.015	0.37	
45	35	0.0090	0.013	0.33	
45	34	0.0095	0.013	0.32	
45	33	0.0102	0.012	0.30	
45	32	0.0112	0.011	0.28	
45	31	0.0122	0.010	0.25	
50	38	0.0057	0.014	0.36	
50	37	0.0065	0.013	0.34	p
50	36	0.0075	0.012	0.32	
50	35	0.0090	0.011	0.28	sd
50	34	0.0095	0.010	0.27	rh
55	38	0.0057	0.012	0.31	
55	37	0.0065	0.012	0.30	
55	36	0.0075	0.011	0.27	
55	35	0.0090	0.009	0.23	t
55	34	0.0095	0.009	0.22	
60	38	0.0057	0.011	0.28	
60	37	0.0065	0.010	0.26	
60	36	0.0075	0.009	0.23	d
60	35	0.0090	0.008	0.19	f
60	34	0.0095	0.007	0.18	s
64	39	0.0050	0.011	0.27	
64	38	0.0057	0.010	0.25	
64	37	0.0065	0.009	0.23	
64	36	0.0075	0.008	0.21	
64	35	0.0090	0.007	0.17	
70	40	0.0045	0.010	0.25	
70	39	0.0050	0.009	0.23	
70	38	0.0057	0.008	0.21	r
70	37	0.0065	0.008	0.20	d
70	36	0.0075	0.007	0.17	
74	41	0.0042	0.009	0.24	
74	40	0.0045	0.009	0.23	
74	39	0.0050	0.008	0.22	
74	38	0.0057	0.008	0.20	
74	37	0.0065	0.007	0.18	
80	41	0.0042	0.008	0.21	
80	40	0.0045	0.008	0.20	
80	39	0.0050	0.007	0.19	
80	38	0.0057	0.007	0.17	tsd
80	37	0.0065	0.0060	0.15	
90	41	0.0042	0.0068	0.17	
90	40	0.0045	0.0066	0.16	h
90	39	0.0050	0.0061	0.15	d
90	38	0.0057	0.0054	0.13	t
90	37	0.0065	0.0046	0.12	
100	43	0.0036	0.0064	0.163	
100	42	0.0040	0.0060	0.152	
100	41	0.0042	0.0057	0.146	
100	40	0.0045	0.0055	0.140	ds
100	39	0.0050	0.0050	0.127	
100	38	0.0057	0.0042	0.108	
110	42	0.0040	0.0059	0.150	
110	41	0.0042	0.0046	0.118	h
120	44	0.0032	0.0051	0.130	
120	43	0.0036	0.0047	0.120	
120	42	0.0040	0.0043	0.109	ds
130	44	0.0032	0.0045	0.114	
130	43	0.0036	0.0041	0.104	
140	45	0.0028	0.0043	0.110	
140	44	0.0032	0.0039	0.100	f
150	46	0.0024	0.0042	0.107	
150	45	0.0028	0.0038	0.097	
150	44½	0.0030	0.0036	0.091	d
150	44	0.0032	0.0034	0.086	t
150	43	0.0036	0.0030	0.076	
150	42	0.0040	0.0026	0.066	
160	45½	0.0026	0.0036	0.091	
160	45	0.0028	0.0034	0.086	
160	44½	0.0030	0.0032	0.081	
160	44	0.0032	0.0030	0.076	
160	43	0.0036	0.0026	0.066	t
160	42	0.0040	0.0022	0.056	
170	45½	0.0026	0.0033	0.084	
170	45	0.0028	0.0031	0.079	
170	44½	0.0030	0.0029	0.074	
170	44	0.0032	0.0027	0.069	
170	43	0.0036	0.0023	0.058	
170	42	0.0040	0.0019	0.048	
180	46½	0.0022	0.0033	0.084	
180	46	0.0024	0.0031	0.079	
180	45½	0.0026	0.0029	0.074	h
180	45	0.0028	0.0027	0.069	
180	44½	0.0030	0.0025	0.063	
180	44	0.0032	0.0023	0.058	
180	43	0.0036	0.0019	0.048	t
180	42	0.0040	0.0015	0.038	
190	47	0.0020	0.0032	0.081	
190	46½	0.0022	0.0030	0.076	
190	46	0.0024	0.0028	0.071	
190	45½	0.0026	0.0026	0.066	
190	45	0.0028	0.0024	0.061	
190	44½	0.0030	0.0022	0.056	
190	44	0.0032	0.0020	0.051	
190	43	0.0036	0.0016	0.041	
190	42	0.0040	0.0012	0.030	t
200	47	0.0020	0.0030	0.076	
200	46½	0.0022	0.0028	0.071	
200	46	0.0024	0.0026	0.066	
200	45½	0.0026	0.0024	0.061	
200	45	0.0028	0.0022	0.056	
200	44½	0.0030	0.0020	0.051	f
200	44	0.0032	0.0018	0.046	
200	43	0.0036	0.0014	0·036	
200	42	0.0040	0.0010	0.025	t

d. De Kalb screens. *f*. Nearest approach to sizes of graded set, 1", ½", ¼", etc. *h*. Richards (Hutchinson) screens. *p*. Nearest size to punched screens, Table II. *s*. Brunton's screens. *t*. Sizes in Table I. *r*. Rittinger's screens.

TABLE V.—*Sizes of Wire Screens (mostly of brass in the coarse sizes) of the Birmingham (or Stub's) Gauge.*

Mesh.	Wire.		Space.		Reference.
	B. or S.	Diameter in Inches.	Inches.	Milli-meters.	
Inches to the mesh.					
3″	0	0.340	2.66	67.6	
3″	00	0.380	2.62	66.5	r
3″	000	0.425	2.57	65.3	t
2½″	1	0.300	2.20	55.9	
2½″	0	0.340	2.16	54.9	
2½″	00	0.380	2.12	53.8	f
2⅛″	0	0.340	1.78	45.2	rt
1½″	3	0.259	1.24	31.5	t
1½″	2	0.284	1.22	31.0	r
1½″	1	0.300	1.12	28.4	
1⅛″	4	0.238	0.887	22.5	rt
1″	15	0.072	0.938	23.8	f
1″	14	0.083	0.917	23.3	
1″	13	0.095	0.905	23.0	
1″	12	0.109	0.891	22.6	
1″	11	0.120	0.880	22.3	
1″	10	0.134	0.866	22.0	
1″	9	0.148	0.852	21.6	
1″	8	0.165	0.835	21.2	
1″	7	0.180	0.820	20.8	
1″	6	0.203	0.797	20.2	
1″	5	0.220	0.780	19.8	
1″	4	0.238	0.762	19.3	
1″	3	0.259	0.741	18.8	
¾″	16	0.065	0.685	17.4	
¾″	15	0.072	0.678	17.2	
¾″	14	0.083	0.667	16.9	
¾″	13	0.095	0.655	16.6	
¾″	12	0.109	0.641	16.3	
¾″	11	0.120	0.630	16.0	t
¾″	10	0.134	0.616	15.6	
¾″	9	0.148	0.602	15.3	
¾″	8	0.165	0.585	14.9	
¾″	7	0.180	0.570	14.5	
¾″	6	0.203	0.547	13.9	
¾″	5	0.220	0.530	13.5	
¾″	4	0.238	0.512	13.0	
⅝″	17	0.058	0.567	14.4	
⅝″	16	0.065	0.560	14.2	
⅝″	15	0.072	0.553	14.0	
⅝″	14	0.083	0.542	13.8	
⅝″	13	0.095	0.530	13.5	
⅝″	12	0.109	0.516	13.1	
⅝″	11	0.120	0.505	12.8	f
⅝″	10	0.134	0.491	13.5	
⅝″	9	0.148	0.477	12.1	
⅝″	8	0.165	0.460	11.7	r
⅝″	7	0.180	0.445	11.3	t
⅝″	6	0.203	0.422	10.7	
⅝″	5	0.220	0.405	10.3	
Meshes to the inch.					
2	18	0.049	0.451	11.5	
2	17	0.058	0.442	11.2	
2	16	0.065	0.435	11.0	
2	15	0.072	0.428	10.9	
2	14	0.083	0.417	10.6	
2	13	0.095	0.405	10.3	
2	12	0.109	0.391	9.93	
2	11	0.120	0.380	9.65	
2	10	0.134	0.366	9.30	
2	9	0.148	0.352	8.94	
2	8	0.165	0.335	8.51	
2½	19	0.042	0.358	9.09	
2½	18	0.049	0.351	8.92	
2½	17	0.058	0.342	8.69	
2½	16	0.065	0.335	8.51	
2½	15	0.072	0.328	8.33	
2½	14	0.083	0.317	8.05	t
2½	13	0.095	0.305	7.75	
2½	12	0.109	0.291	7.39	r
2½	11	0.120	0.280	7.11	
2½	10	0.134	0.266	6.76	
2½	9	0.148	0.252	6.40	

Mesh.	Wire.		Syace.		Reference.
	B. or S.	Diameter in Inches.	Inches.	Milli-meters.	
Meshes to the inch.					
3	20	0.035	0.298	7.57	
3	19	0.042	0.291	7.39	
3	18	0.049	0.284	7.21	
3	17	0.058	0.275	6.98	
3	16	0.065	0.268	6.81	
3	15	0.072	0.261	6.63	
3	14	0.083	0.250	6.35	
3	13	0.095	0.238	6.05	
3	12	0.109	0.224	5.69	
3	11	0.120	0.213	5.41	
3	10	0.134	0.199	5.05	
3½	20	0.035	0.250	6.35	
3½	19	0.042	0.243	6.17	
3½	18	0.049	0.236	5.99	
3½	17	0.058	0.227	5.77	
3½	16	0.065	0.220	5.59	t
3½	15	0.072	0.213	5.41	
3½	14	0.083	0.202	5.13	r
3½	13	0.095	0.190	4.83	
3½	12	0.109	0.176	4.48	
3½	11	0.120	0.165	4.19	
4	21	0.032	0.218	5.54	
4	20	0.035	0.215	5.46	
4	19	0.042	0.208	5.28	
4	18	0.049	0.201	5.11	
4	17	0.058	0.192	4.88	
4	16	0.065	0.185	4.70	
4	15	0.072	0.178	4.52	
4	14	0.083	0.167	4.24	
4	13	0.095	0.155	3.94	
4	12	0.109	0.141	3.58	
4	11	0.120	0.130	3.29	
4½	21	0.032	0.190	4.83	
4½	20	0.035	0.187	4.75	
4½	19	0.042	0.180	4.57	
4½	18	0.049	0.173	4.39	
4½	17	0.058	0.164	4.17	
4½	16	0.065	0.157	3.99	t
4½	15	0.072	0.150	3.81	r
4½	14	0.083	0.139	3.53	
4½	13	0.095	0.127	3.23	
4½	12	0.109	0.113	2.84	
5	24	0.022	0.178	4.52	
5	23	0.025	0.175	4.44	
5	22	0.028	0.172	4.37	
5	21	0.032	0.168	4.27	
5	20	0.035	0.165	4.19	
5	19	0.042	0.158	4.01	
5	18	0.049	0.151	3.84	
5	17	0.058	0.142	3.61	
5	16	0.065	0.135	3.43	
5	15	0.072	0.128	3.24	
5	14	0.083	0.117	2.97	
5	13	0.095	0.105	2.67	
6	25	0.020	0.146	3.71	
6	24	0.022	0.144	3.66	
6	23	0.025	0.141	3.58	
6	22	0.028	0.138	3.51	
6	21	0.032	0.134	3.40	
6	20	0.035	0.131	3.33	
6	19	0.042	0.124	3.15	f
6	18	0.049	0.117	2.97	
6	17	0.058	0.108	2.74	
6	16	0.065	0.101	2.57	r
6	15	0.072	0.094	2.39	
6	14	0.083	0.083	2.11	
7	26	0.018	0.125	3.17	
7	25	0.020	0.123	3.12	
7	24	0.022	0.121	3.07	
7	23	0.025	0.118	3.00	
7	22	0.028	0.115	2.92	
7	21	0.032	0.111	2.82	t

f. Nearest approach to sizes of graded set, 1″, ½″, ¼″, etc. *p.* nearest size to punched screens, Table II. *t.* Sizes in Table I. *r.* Rittinger's screens.

TABLE V.—*Continued.*

Mesh. Meshes to the inch.	Wire.		Space.		Reference.	Mesh. Meshes to the inch.	Wire.		Space.		Reference.
	B. or S.	Diameter in Inches.	Inches.	Milli-meters.			B. or S.	Diameter in Inches.	Inches.	Milli-meters.	
7	20	0.035	0.108	2.74		16	23	0.025	0.037	0.94	
7	19	0.042	0.103	2.62		16	22	0.028	0.034	0.86	
7	18	0.049	0.094	2.32		16	21	0.032	0.030	0.76	
7	17	0.058	0.085	2.16		16	20	0.035	0.027	0.69	
7	16	0.065	0.078	1.98		18	31	0.010	0.045	1.14	
7	15	0.072	0.071	1.80		18	30	0.012	0.043	1.09	
8	27	0.016	0.109	2.77		18	29	0.013	0.042	1.07	
8	26	0.018	0.107	2.72		18	28	0.014	0.041	1.04	
8	25	0.020	0.105	2.67		18	27	0.016	0.039	0.99	
8	24	0.022	0.103	2.62		18	26	0.018	0.037	0.94	
8	23	0.025	0.100	2.54		18	25	0.020	0.035	0.89	
8	22	0.028	0.097	2.46		18	24	0.022	0.033	0.84	
8	21	0.032	0.093	2.36		18	23	0.025	0.030	0.76	
8	20	0.035	0.090	2.29		18	22	0.028	0.027	0.69	
8	19	0.042	0.083	2.11		18	21	0.032	0.023	0.58	
8	18	0.049	0.076	1.93	r	20	32	0.009	0.041	1.04	
8	17	0.058	0.067	1.70		20	31	0.010	0.040	1.01	
8	16	0.065	0.060	1.52		20	30	0.012	0.038	0.96	
9	28	0.014	0.097	2.46		20	29	0.013	0.037	0.94	
9	27	0.016	0.095	2.41		20	28	0.014	0.036	0.91	
9	26	0.018	0.093	2.36		20	27	0.016	0.034	0.86	
9	25	0.020	0.091	2.31		20	26	0.018	0.032	0.81	
9	24	0.022	0.089	2.27		20	25	0.020	0.030	0.76	
9	23	0.025	0.086	2.18		20	24	0.022	0.028	0.71	
9	22	0.028	0.083	2.11		20	23	0.025	0.025	0.63	
9	21	0.032	0.079	2.01	t	20	22	0.028	0.022	0.56	
9	20	0.035	0.076	1.93		22	32	0.009	0.038	0.96	
9	19	0.042	0.069	1.75		22	31	0.010	0.037	0.94	
9	18	0.049	0.062	1.57		22	30	0.012	0.035	0.89	p
9	17	0.058	0.053	1.35		22	29	0.013	0.034	0.86	
10	29	0.013	0.087	2.21		22	28	0.014	0.033	0.84	
10	28	0.014	0.086	2.18		22	27	0.016	0.031	0.79	f
10	27	0.016	0.084	2.13		22	26	0.018	0.029	0.74	
10	26	0.018	0.082	2.08		22	25	0.020	0.027	0.68	
10	25	0.020	0.080	2.03		22	24	0.022	0.025	0.63	
10	24	0.022	0.078	1.98		22	23	0.025	0.022	0.56	
10	23	0.025	0.075	1.90		24	34	0.007	0.035	0.89	
10	22	0.028	0.072	1.83		24	33	0.008	0.034	0.86	
10	21	0.032	0.068	1.73		24	32	0.009	0.033	0.84	
10	20	0.035	0.065	1.65	f	24	31	0.010	0.032	0.81	
10	19	0.042	0.058	1.47		24	30	0.012	0.030	0.76	
10	18	0.049	0.051	1.30		24	29	0.013	0.029	0.74	
12	30	0.012	0.071	1.80		24	28	0.014	0.028	0.71	rt
12	29	0.013	0.070	1.78		24	27	0.016	0.026	0.66	
12	28	0.014	0.069	1.75		24	26	0.018	0.023	0.61	
12	27	0.016	0.067	1.70		24	25	0.020	0.022	0.56	
12	26	0.018	0.065	1.65		24	24	0.022	0.020	0.51	
12	25	0.020	0.063	1.60		24	23	0.025	0.017	0.43	
12	24	0.022	0.061	1.55		26	34	0.007	0.031	0.79	
12	23	0.025	0.058	1.47	p	26	33	0.008	0.030	0.76	
12	22	0.028	0.055	1.40	rt	26	32	0.009	0.029	0.74	p
12	21	0.032	0.051	1.30		26	31	0.010	0.028	0.71	
12	20	0.035	0.048	1.22		26	30	0.012	0.026	0.66	
12	19	0.042	0.041	1.04		26	29	0.013	0.025	0.63	
14	30	0.012	0.059	1.50		26	28	0.014	0.024	0.61	
14	29	0.013	0.058	1.47		26	27	0.016	0.022	0.56	
14	28	0.014	0.057	1.45		26	26	0.018	0.020	0.51	
14	27	0.016	0.055	1.40		26	25	0.020	0.018	0.46	
14	26	0.018	0.053	1.35		26	24	0.022	0.016	0.41	
14	25	0.020	0.051	1.30		28	34	0.007	0.029	0.73	
14	24	0.022	0.049	1.24	p	28	33	0.008	0.028	0.71	
14	23	0.025	0.046	1.17		28	32	0.009	0.027	0.68	p
14	22	0.028	0.044	1.12		28	31	0.010	0.026	0.66	
14	21	0.032	0.039	0.99		28	30	0.012	0.024	0.61	
14	20	0.036	0.036	0.91		28	29	0.013	0.023	0.58	
16	30	0.012	0.050	1.27		28	28	0.014	0.022	0.56	
16	29	0.013	0.049	1.24		28	27	0.016	0.020	0.51	
16	28	0.014	0.048	1.22		28	26	0.018	0.018	0.46	
16	27	0.016	0.046	1.17		28	25	0.020	0.016	0.41	
16	26	0.018	0.044	1.12		30	34	0.007	0.026	0.66	
16	25	0.020	0.042	1.07	rp	30	33	0.008	0.025	0.63	
16	24	0.022	0.040	1.02	t	30	32	0.009	0.024	0.61	p

f. Nearest approach to sizes of graded set, 1″, ½″, ¼″, etc. *p*. Nearest size to punched screens, Table II. *t*. Sizes in Table I. *r*. Rittinger's screens.

TABLE V.—*Concluded.*

	Mesh.	Wire.		Space.		Reference.		Mesh.	Wire.		Space.		Reference.
		B. or S.	Diameter in Inches.	Inches.	Milli-meters.				B. or S.	Diameter in Inches.	Inches.	Milli-meters.	
Meshes to the inch.	30	31	0.010	0.023	0.58	p	Meshes to the inch.	55	31	0.010	0.008	0.20	
	30	30	0.012	0.021	0.53			55	30	0.012	0.006	0.15	
	30	29	0.013	0.020	0.51	tp		60	34	0.007	0.010	0.25	
	30	28	0.014	0.019	0.48			60	33	0.008	0.009	0.23	
	30	27	0.016	0.017	0.43			60	32	0.009	0.008	0.20	f
	30	26	0.018	0.015	0.38			60	31	0.010	0.007	0.18	
	30	25	0.020	0.013	0.33			60	30	0.012	0.005	0.13	
	35	34	0.007	0.021	0.53			64	34	0.007	0.009	0.23	
	35	33	0.008	0.020	0.51			64	33	0.008	0.008	0.20	
	35	32	0.009	0.019	0.48			64	32	0.009	0.007	0.18	t
	35	31	0.010	0.018	0.46	rp		64	31	0.010	0.006	0.15	
	35	30	0.012	0.016	0.41	p		64	30	0.012	0.004	0.10	
	35	29	0.013	0.015	0.38	f		70	35	0.005	0.009	0.23	
	35	28	0.014	0.014	0.35			70	34	0.007	0.007	0.18	
	35	27	0.016	0.012	0.30			70	33	0.008	0.006	0.15	
	35	26	0.018	0.010	0.25			70	32	0.009	0.005	0.13	
	40	34	0.007	0.018	0.46			70	31	0.010	0.004	0.10	
	40	33	0.008	0.017	0.43			74	35	0.005	0.008	0.20	
	40	32	0.009	0.016	0.41			74	34	0.007	0.006	0.15	
	40	31	0.010	0.015	0.38	p		74	33	0.008	0.005	0.13	t
	40	30	0.012	0.013	0.33	t		74	32	0.009	0.004	0.10	
	40	29	0.013	0.012	0.30			74	31	0.010	0.003	0.08	
	40	28	0.014	0.011	0.28			80	36	0.004	0.008	0.20	
	45	34	0.007	0.015	0.38			80	35	0.005	0.007	0.18	
	45	33	0.008	0.014	0.35	p		80	34	0.007	0.005	0.13	
	45	32	0.009	0.013	0.33			80	33	0.008	0.004	0.10	
	45	31	0.010	0.012	0.30			80	32	0.009	0.003	0.08	
	45	30	0.012	0.010	0.25			90	36	0.004	0.007	0.18	
	45	29	0.013	0.009	0.23			90	35	0.005	0.006	0.15	
	50	34	0.007	0.013	0.33	r		90	34	0.007	0.004	0.10	f
	50	33	0.008	0.012	0.30			90	33	0.008	0.003	0.08	
	50	32	0.009	0.011	0.28			90	32	0.009	0.002	0.05	
	50	31	0.010	0.010	0.25	t		100	36	0.004	0.006	0.15	
	50	30	0.012	0.008	0.20			100	35	0.005	0.005	0.13	
	55	34	0.007	0.011	0.28			100	34	0.007	0.003	0.08	t
	55	33	0.008	0.010	0.25			100	33	0.008	0.002	0.05	
	55	32	0.009	0.009	0.23								

f. Nearest approach to sizes of graded set, 1″, ½″, ¼″, etc. *p.* Nearest size to punched screens, Table II. *t.* Sizes in Table I. *r.* Rittinger's screens.

Table VI.—*Sizes of Wire Screens (usually copper) of the American (or Brown & Sharpe) Gauge.*

	Mesh.	Wire.		Space.		Reference.
		B. & S.	Diameter in Inches.	Inches.	Milli-meters.	
Inches to the mesh.	3''	0	0.3248	2.67	68.0	
	3''	00	0.3648	2.63	66.8	r
	3''	000	0.4096	2.59	65.8	t
	2½''	1	0.2893	2.21	56.1	
	2½''	0	0.3248	2.17	55.2	
	2½''	00	0.3648	2.13	54.2	f
	2⅛''	0	0.3248	1.80	45.7	rt
	1½''	3	0.2294	1.27	32.3	t
	1½''	2	0.2576	1.24	31.5	r
	1½''	1	0.2893	1.21	30.7	
	1⅛''	4	0.2043	0.92	23.4	rt
	1''	15	0.0570	0.943	23.9	f
	1''	14	0.0640	0.936	23.8	
	1''	13	0.0719	0.928	23.6	
	1''	12	0.0808	0.919	23.3	
	1''	11	0.0907	0.909	23.1	
	1''	10	0.1018	0.898	22.8	
	1''	9	0.1144	0.886	22.5	
	1''	8	0.1284	0.872	22.1	
	1''	7	0.1442	0.856	21.7	
	1''	6	0.1620	0.838	21.3	
	1''	5	0.1819	0.818	20.8	
	1''	4	0.2043	0.796	20.2	
	1''	3	0.2294	0.771	19.6	
	¾''	16	0.0508	0.699	17.7	
	¾''	15	0.0570	0.693	17.6	
	¾''	14	0.0641	0.686	17.4	
	¾''	13	0.0719	0.678	17.2	
	¾''	12	0.0808	0.669	17.0	
	¾''	11	0.0907	0.659	16.7	
	¾''	10	0.1018	0.648	16.5	
	¾''	9	0.1144	0.636	16.1	t
	¾''	8	0.1284	0.622	15.8	
	¾''	7	0.1442	0.606	15.4	
	¾''	6	0.1620	0.588	14.9	
	¾''	5	0.1819	0.568	14.4	
	¾''	4	0.2043	0.546	13.9	
	⅝''	17	0.0452	0.580	14.7	
	⅝''	16	0.0508	0.574	14.5	
	⅝''	15	0.0570	0.568	14.4	
	⅝''	14	0.0640	0.561	14.2	
	⅝''	13	0.0719	0.553	14.0	
	⅝''	12	0.0808	0.544	13.8	
	⅝''	11	0.0907	0.534	13.6	
	⅝''	10	0.1018	0.523	13.3	
	⅝''	9	0.1144	0.510	12.9	
	⅝''	8	0.1284	0.497	12.6	rf
	⅝''	7	0.1442	0.481	12.2	
	⅝''	6	0.1620	0.463	11.8	
	⅝''	5	0.1819	0.443	11.2	
Meshes to the inch.	2	19	0.0358	0.464	11.79	
	2	18	0.0403	0.460	11.68	
	2	17	0.0452	0.455	11.56	
	2	16	0.0508	0.449	11.40	
	2	15	0.0570	0.443	11.25	t
	2	14	0.0640	0.436	11.07	
	2	13	0.0719	0.428	10.87	
	2	12	0.0808	0.419	10.64	
	2	11	0.0907	0.409	10.39	
	2	10	0.1018	0.398	10.11	
	2	9	0.1144	0.386	9.80	
	2	8	0.1284	0.372	9.45	
	2	7	0.1442	0.356	9.04	
	2	6	0.1620	0.338	8.59	
	2½	19	0.0358	0.364	9.25	
	2½	18	0.0403	0.360	9.14	
	2½	17	0.0452	0.355	9.02	
	2½	16	0.0508	0.349	8.86	
	2½	15	0.0570	0.343	8.71	
	2½	14	0.0640	0.336	8.53	
	2½	13	0.0719	0.328	8.33	
	2½	12	0.0808	0.319	8.10	rt
	2½	11	0.0907	0.309	7.85	
	2½	10	0.1018	0.298	7.57	
	2½	9	0.1144	0.286	7.26	
	2½	8	0.1284	0.272	6.91	
	3	20	0.0319	0.301	7.65	
	3	19	0.0358	0.297	7.54	
	3	18	0.0403	0.293	7.44	
	3	17	0.0452	0.288	7.32	
	3	16	0.0508	0.282	7.16	
	3	15	0.0570	0.274	6.96	
	3	14	0.0640	0.269	6.83	
	3	13	0.0719	0.261	6.63	
	3	12	0.0808	0.252	6.40	f
	3	11	0.0907	0.243	6.17	
	3	10	0.1018	0.231	5.87	
	3	9	0.1144	0.220	5.59	
	3	8	0.1284	0.205	5.21	
	3½	21	0.0284	0.257	6.53	
	3½	20	0.0319	0.254	6.45	
	3½	19	0.0358	0.250	6.35	
	3½	18	0.0403	0.244	6.20	
	3½	17	0.0452	0.239	6.07	
	3½	16	0.0508	0.235	5.97	
	3½	15	0.0570	0.229	5.82	
	3½	14	0.0640	0.222	5.64	rt
	3½	13	0.0719	0.213	5.41	
	3½	12	0.0808	0.205	5.20	
	3½	11	0.0907	0.195	4.95	
	4	22	0.0253	0.225	5.71	
	4	21	0.0284	0.222	5.64	
	4	20	0.0319	0.218	5.54	
	4	19	0.0358	0.214	5.44	
	4	18	0.0403	0.210	5.33	
	4	17	0.0452	0.207	5.26	
	4	16	0.0508	0.199	5.05	
	4	15	0.0570	0.193	4.90	
	4	14	0.0640	0.186	4.72	
	4	13	0.0719	0.178	4.52	
	4	12	0.0808	0.169	4.29	
	4	11	0.0907	0.159	4.04	
	4	10	0.1018	0.148	3.76	
	4	9	0.1144	0.136	3.45	
	4½	23	0.0225	0.200	5.08	
	4½	22	0.0253	0.197	5.00	
	4½	21	0.0284	0.194	4.93	
	4½	20	0.0319	0.190	4.83	
	4½	19	0.0358	0.186	4.72	
	4½	18	0.0403	0.182	4.62	
	4½	17	0.0452	0.177	4.50	
	4½	16	0.0508	0.171	4.34	
	4½	15	0.0570	0.165	4.19	rt
	4½	14	0.0640	0.158	4.01	
	4½	13	0.0719	0.150	3.81	
	4½	12	0.0808	0.141	3.58	
	5	23	0.0225	0.177	4.50	
	5	22	0.0253	0.175	4.44	
	5	21	0.0284	0.172	4.37	
	5	20	0.0319	0.168	4.27	
	5	19	0.0388	0.164	4.17	
	5	18	0.0403	0.160	4.06	
	5	17	0.0452	0.155	3.94	
	5	16	0.0508	0.149	3.78	
	5	15	0.0570	0.143	3.63	
	5	14	0.0648	0.135	3.43	
	5	13	0.0719	0.128	3.25	
	5	12	0.0808	0.119	3.02	
	5	11	0.0907	0.109	2.77	
	6	25	0.0179	0.149	3.78	
	6	24	0.0201	0.146	3.71	
	6	23	0.0225	0.144	3.66	
	6	22	0.0253	0.141	3.58	
	6	21	0.0284	0.137	3.48	

f. Nearest approach to sizes of graded set, 1'', ½'', ¼'', etc. *p*. Nearest size to punched screens, Table II. *t*. Sizes in Table I. *r*. Rittinger's screens.

TABLE VI.—*Continued.*

Mesh.	Wire.		Space.		Reference.
Meshes to the inch.	B. & S.	Diameter in Inches.	Inches.	Milli-meters.	
6	20	0.0319	0.135	3.43	
6	19	0.0358	0.131	3.33	
6	18	0.0403	0.126	3.20	f
6	17	0.0452	0.121	3.07	
6	16	0.0508	0.116	2.95	r
6	15	0.0570	0.110	2.79	
6	14	0.0640	0.092	2.34	
6	13	0.0719	0.085	2.16	
6	12	0.0808	0.076	1.93	
7	26	0.0159	0.127	3.23	
7	25	0.0179	0.125	3.17	
7	24	0.0201	0.123	3.12	
7	23	0.0225	0.120	3.05	
7	22	0.0253	0.117	2.97	
7	21	0.0284	0.114	2.90	
7	20	0.0319	0.111	2.82	t
7	19	0.0358	0.107	2.72	
7	18	0.0403	0.102	2.59	
7	17	0.0452	0.098	2.49	
7	16	0.0508	0.092	2.34	
7	15	0.0570	0.086	2.18	
8	27	0.0141	0.111	2.82	
8	26	0.0159	0.109	2.77	
8	25	0.0179	0.107	2.72	
8	24	0.0201	0.105	2.67	
8	23	0.0225	0.102	2.59	
8	22	0.0253	0.100	2.54	
8	21	0.0284	0.097	2.46	
8	20	0.0319	0.093	2.36	
8	19	0.0358	0.089	2.26	
8	18	0.0403	0.085	2.16	r
8	17	0.0452	0.080	2.03	
8	16	0.0508	0.074	1.88	
8	15	0.0570	0.068	1.73	
8	14	0.0640	0.061	1.55	
9	28	0.0126	0.098	2.49	
9	27	0.0141	0.096	2.44	
9	26	0.0159	0.095	2.41	
9	25	0.0179	0.093	2.36	
9	24	0.0201	0.091	2.31	
9	23	0.0225	0.089	2.26	
9	22	0.0253	0.086	2.18	
9	21	0.0284	0.083	2.11	
9	20	0.0319	0.079	2.00	t
9	19	0.0358	0.075	1.90	
9	18	0.0403	0.071	1.80	
9	17	0.0452	0.066	1.68	
10	29	0.0112	0.089	2.26	
10	28	0.0126	0.087	2.21	
10	27	0.0141	0.086	2.18	
10	26	0.0159	0.084	2.13	
10	25	0.0179	0.082	2.08	
10	24	0.0201	0.080	2.03	
10	23	0.0225	0.077	1.96	
10	22	0.0253	0.075	1.90	
10	21	0.0284	0.072	1.83	
10	20	0.0319	0.068	1.73	
10	19	0.0358	0.064	1.63	f
10	18	0.0403	0.060	1.52	
10	17	0.0452	0.055	1.40	
10	16	0.0508	0.049	1.24	
12	30	0.0100	0.073	1.85	
12	29	0.0112	0.072	1.84	
12	28	0.0126	0.071	1.83	
12	27	0.0141	0.069	1.75	
12	26	0.0159	0.067	1.70	
12	25	0.0179	0.065	1.65	
12	24	0.0201	0.063	1.60	
12	23	0.0225	0.061	1.55	
12	22	0.0254	0.058	1.47	rp
12	21	0.0284	0.055	1.40	t
12	20	0.0319	0.051	1.30	
12	19	0.0358	0.047	1.19	
12	18	0.0403	0.043	1.09	
14	34	0.0063	0.065	1.65	
14	33	0.0070	0.064	1.63	
14	32	0.0079	0.063	1.60	
14	31	0.0089	0.062	1.57	
14	30	0.0100	0.061	1.55	
14	29	0.0112	0.060	1.52	
14	28	0.0126	0.059	1.50	
14	27	0.0141	0.057	1.45	
14	26	0.0159	0.055	1.40	
14	25	0.0179	0.053	1.35	
14	24	0.0201	0.051	1.30	
14	23	0.0225	0.049	1.24	
14	22	0.0253	0.046	1.17	
14	21	0.0284	0.043	1.09	
14	20	0.0319	0.039	0.99	
16	35	0.0056	0.057	1.45	
16	34	0.0063	0.056	1.42	
16	33	0.0070	0.055	1.40	
16	32	0.0079	0.054	1.37	
16	31	0.0089	0.053	1.35	
16	30	0.0100	0.052	1.32	
16	29	0.0112	0.051	1.30	
16	28	0.0126	0.050	1.27	
16	27	0.0141	0.048	1.23	p
16	26	0.0159	0.047	1.19	
16	25	0.0179	0.045	1.14	r
16	24	0.0201	0.042	1.07	
16	23	0.0225	0.040	1.02	t
16	22	0.0253	0.037	0.94	
16	21	0.0284	0.034	0.86	
18	36	0.0050	0.051	1.28	
18	35	0.0056	0.050	1.27	
18	34	0.0063	0.049	1.25	
18	33	0.0070	0.048	1.23	
18	32	0.0079	0.047	1.21	
18	31	0.0089	0.046	1.18	
18	30	0.0100	0.045	1.17	
18	29	0.0112	0.044	1.13	
18	28	0.0126	0.042	1.09	
18	27	0.0141	0.041	1.04	
18	26	0.0159	0.039	0.98	
18	25	0.0179	0.038	0.97	
18	24	0.0201	0.035	0.89	
18	23	0.0225	0.033	0.84	
18	22	0.0253	0.030	0.76	
20	36	0.0050	0.045	1.14	
20	35	0.0056	0.044	1.13	
20	34	0.0063	0.043	1.12	
20	33	0.0070	0.042	1.09	
20	32	0.0079	0.042	1.07	p
20	31	0.0089	0.041	1.04	
20	30	0.0100	0.039	1.01	
20	29	0.0112	0.038	0.99	
20	28	0.0126	0.037	0.95	
20	27	0.0141	0.035	0.91	
20	26	0.0159	0.034	0.86	
20	25	0.0179	0.032	0.82	
20	24	0.0201	0.029	0.76	
20	23	0.0225	0.027	0.70	
22	36	0.0050	0.042	1.07	
22	35	0.0056	0.041	1.06	
22	34	0.0063	0.041	1.04	
22	33	0.0070	0.040	1.02	
22	32	0.0079	0.039	1.00	
22	31	0.0089	0.038	0.97	
22	30	0.0100	0.037	0.94	
22	29	0.0112	0.036	0.91	
22	28	0.0126	0.034	0.88	
22	27	0.0141	0.033	0.84	
22	26	0.0159	0.031	0.79	

f. Nearest approach to sizes of graded set, 1″, ½″, ¼″, etc. *p.* Nearest size to punched screens, Table II. *t.* Sizes in Table I. *r.* Rittinger's screens.

TABLE VI.—*Concluded.*

Meshes to the inch.

Mesh.	Wire.		Space.		Reference.
	B. & S.	Diameter in Inches.	Inches.	Milli-meters.	
22	25	0.0179	0.029	0.74	
22	24	0.0201	0.027	0.69	
24	36	0.0050	0.036	0.93	
24	35	0.0056	0.036	0.91	
24	34	0.0063	0.035	0.90	p
24	33	0.0070	0.034	0.88	
24	32	0.0079	0.033	0.86	
24	31	0.0089	0.032	0.83	
24	30	0.0100	0.031	0.80	
24	29	0.0112	0.030	0.77	
24	28	0.0126	0.029	0.74	r
24	27	0.0141	0.027	0.70	t
24	26	0.0159	0.025	0.65	
24	25	0.0179	0.023	0.60	
26	36	0.0050	0.034	0.85	
26	35	0.0056	0.033	0.84	
26	34	0.0063	0.032	0.82	
26	33	0.0070	0.031	0.80	f
26	32	0.0079	0.030	0.77	
26	31	0.0089	0.029	0.75	p
26	30	0.0100	0.028	0.72	
26	29	0.0112	0.027	0.69	p
26	28	0.0126	0.025	0.66	
26	27	0.0141	0.024	0.61	
26	26	0.0159	0.022	0.57	
28	36	0.0050	0.031	0.78	
28	35	0.0056	0.030	0.76	
28	34	0.0063	0.029	0.75	
28	33	0.0070	0.029	0.73	
28	32	0.0079	0.028	0.71	
28	31	0.0089	0.027	0.68	
28	30	0.0100	0.025	0.65	
28	29	0.0112	0.024	0.62	p
28	28	0.0126	0.023	0.59	
28	27	0.0141	0.021	0.55	
30	36	0.0050	0.028	0.72	
30	35	0.0056	0.028	0.70	
30	34	0.0063	0.027	0.69	
30	33	0.0070	0.026	0.67	
30	32	0.0079	0.025	0.65	
30	31	0.0089	0.024	0.62	
30	30	0.0100	0.023	0.59	
30	29	0.0112	0.022	0.56	p
30	28	0.0126	0.021	0.53	
30	27	0.0141	0.019	0.49	
35	37	0.0044	0.024	0.61	
35	36	0.0050	0.023	0.60	
35	35	0.0056	0.023	0.58	
35	34	0.0063	0.022	0.56	
35	33	0.0070	0.021	0.55	
35	32	0.0079	0.021	0.52	
35	31	0.0089	0.020	0.50	rtp
35	30	0.0100	0.018	0.47	
35	29	0.0112	0.017	0.44	
35	28	0.0126	0.016	0.40	

Meshes to the inch.

Mesh.	Wire.		Space.		Reference.
	B. & S.	Diameter in Inches.	Inches.	Milli-meters.	
40	37	0.0044	0.021	0.52	
40	36	0.0050	0.020	0.51	
40	35	0.0056	0.019	0.49	
40	34	0.0063	0.019	0.47	
40	33	0.0070	0.018	0.46	p
40	32	0.0079	0.017	0.43	p
40	31	0.0089	0.016	0.41	f
40	30	0.0100	0.015	0.38	
45	37	0.0044	0.018	0.45	
45	36	0.0050	0.017	0.44	
45	35	0.0056	0.017	0.42	
45	34	0.0063	0.016	0.40	
45	33	0.0070	0.015	0.39	
45	32	0.0079	0.014	0.36	
50	37	0.0044	0.016	0.40	
50	36	0.0050	0.015	0.38	p
50	35	0.0056	0.014	0.37	
50	34	0.0063	0.014	0.35	rtp
50	33	0.0070	0.013	0.33	
50	32	0.0079	0.012	0.31	
60	38	0.0039	0.013	0.32	
60	37	0.0044	0.012	0.31	
60	36	0.0050	0.012	0.29	
60	35	0.0056	0.011	0.28	
60	34	0.0063	0.010	0.26	
64	38	0.0039	0.012	0.30	
64	37	0.0044	0.011	0.28	
64	36	0.0050	0.011	0.27	
64	35	0.0056	0.010	0.25	t
64	34	0.0063	0.009	0.24	
70	38	0.0039	0.010	0.26	r
70	37	0.0044	0.010	0.25	
70	36	0.0050	0.009	0.23	
70	35	0.0056	0.009	0.22	
70	34	0.0063	0.008	0.20	
74	38	0.0039	0.010	0.24	
74	37	0.0044	0.009	0.23	
74	36	0.0050	0.008	0.22	
74	35	0.0056	0.008	0.20	f
74	34	0.0063	0.007	0.18	
80	39	0.0035	0.009	0.23	
80	38	0.0039	0.009	0.22	
80	37	0.0044	0.008	0.21	
80	36	0.0050	0.007	0.19	
80	35	0.0056	0.007	0.18	
90	40	0.0031	0.008	0.20	
90	39	0.0035	0.008	0.19	
90	38	0.0039	0.007	0.18	
90	37	0.0044	0.007	0.17	t
90	36	0.0050	0.006	0.15	
100	40	0.0031	0.007	0.18	
100	39	0.0035	0.006	0.17	
100	38	0.0039	0.006	0.15	
100	37	0.0044	0.006	0.14	
100	36	0.0050	0.005	0.13	t

f. Nearest approach to sizes of graded set, 1″, ½″, ¼″, etc. *p*. Nearest size to punched screens, Table II. *t*. Sizes in Table I. *r*. Rittinger's screens.

TABLE VII.—*Sizes of Wire Screens of the Trenton Standard Gauge.*

		Wire.		Space.					Wire.		Space.		
	Mesh.	Trenton.	Diameter In Inches.	Inches.	Milli-meters.	Reference.		Mesh.	Trenton.	Diameter In Inches.	Inches.	Milli-meters.	Reference.
Inches to the mesh.	3"	0	0.305	2.69	68.3		Meshes to the inch.	2½	9	0.145	0.255	6.48	
	3"	00	0.330	2.67	67.8	r		2½	8	0.160	0.240	6.10	
	3"	000	0.360	2.64	67.1	t		3	20	0.035	0.298	7.57	
	2½"	1	0.285	2.21	56.1			3	19	0.040	0.293	7.44	
	2½"	0	0.305	2.19	55.6			3	18	0.045	0.288	7.31	
	2½"	00	0.330	2.17	55.1	f		3	17	0.052	0.281	7.14	
	2⅛"	0	0.305	1.82	46.2	rt		3	16	0.061	0.272	6.91	
	1½"	3	0.245	1.25	31.7	t		3	15	0.070	0.263	6.68	
	1½"	2	0.265	1.23	31.2	r		3	14	0.080	0.253	6.43	f
	1½"	1	0.285	1.21	30.7			3	13	0.092	0.241	6.12	
	1⅛"	4	0.225	0.90	22.9	rt		3	12	0.105	0.228	5.79	
	1"	15	0.070	0.930	23.6	f		3	11	0.117	0.216	5.49	
	1"	14	0.080	0.920	23.4			3	10	0.130	0.203	5.16	
	1"	13	0.092	0.907	23.0			3½	21	0.031	0.254	6.45	
	1"	12	0.105	0.895	22.7			3½	20	0.035	0.250	6.35	
	1"	11	0.117	0.882	22.4			3½	19	0.040	0.245	6.22	
	1"	10	0.130	0.870	22.1			3½	18	0.045	0.240	6.10	
	1"	9	0.145	0.855	21.7			3½	17	0.052	0.232	5.89	
	1"	8	0.160	0.840	21.3			3½	16	0.061	0.224	5.69	t
	1"	7	0.175	0.825	20.9			3½	15	0.070	0.215	5.46	
	1"	6	0.190	0.810	20.6			3½	14	0.080	0.205	5.21	r
	1"	5	0.205	0.795	20.2			3½	13	0.092	0.192	4.88	
	1"	4	0.225	0.775	19.7			3½	12	0.105	0.180	4.57	
	1"	3	0.245	0.755	19.2			3½	11	0.117	0.167	4.24	
	¾"	16	0.061	0.689	17.5			4	22	0.028	0.222	5.64	
	¾"	15	0.070	0.680	17.3			4	21	0.031	0.219	5.56	
	¾"	14	0.080	0.670	17.0			4	20	0.035	0.215	5.46	
	¾"	13	0.092	0.657	16.7			4	19	0.040	0.210	5.33	
	¾"	12	0.105	0.645	16.4			4	18	0.045	0.205	5.21	
	¾"	11	0.117	0.632	16.0	t		4	17	0.052	0.197	5.00	
	¾"	10	0.130	0.620	15.7			4	16	0.061	0.189	4.80	
	¾"	9	0.145	0.605	15.4			4	15	0.070	0.180	4.57	
	¾"	8	0.160	0.590	15.0			4	14	0.080	0.170	4.32	
	¾"	7	0.175	0.575	14.6			4	13	0.092	0.157	3.99	t
	¾"	6	0.190	0.560	14.2			4	12	0.105	0.145	3.68	
	¾"	5	0.205	0.545	13.8			4	11	0.117	0.132	3.35	
	¾"	4	0.225	0.525	13.3			4½	23	0.025	0.197	5.00	
	⅝"	17	0.052	0.572	14.5			4½	22	0.028	0.194	4.93	
	⅝"	16	0.061	0.564	14.3			4½	21	0.031	0.191	4.85	
	⅝"	15	0.070	0.555	14.1			4½	20	0.035	0.187	4.75	
	⅝"	14	0.080	0.545	13.8			4½	19	0.040	0.182	4.62	
	⅝"	13	0.092	0.532	13.5			4½	18	0.045	0.177	4.49	
	⅝"	12	0.105	0.520	13.2			4½	17	0.052	0.170	4.32	
	⅝"	11	0.117	0.507	12.9			4½	16	0.061	0.161	4.09	
	⅝"	10	0.130	0.495	12.6	f		4½	15	0.070	0.152	3.86	r
	⅝"	9	0.145	0.480	12.2			4½	14	0.080	0.142	3.61	
	⅝"	8	0.160	0.465	11.8	r		4½	13	0.092	0.130	3.30	
	⅝"	7	0.175	0.450	11.4	t		4½	12	0.105	0.117	2.97	
	⅝"	6	0.190	0.435	11.0			5	24	0.022	0.177	4.49	
	⅝"	5	0.205	0.410	10.4			5	23	0.025	0.175	4.44	
Meshes to the inch.	2	18	0.045	0.455	11.56			5	22	0.028	0.172	4.37	
	2	17	0.052	0.447	11.35			5	21	0.031	0.169	4.29	
	2	16	0.061	0.439	11.15			5	20	0.035	0.165	4.19	
	2	15	0.070	0.430	10.92			5	19	0.040	0.160	4.06	
	2	14	0.080	0.420	10.67			5	18	0.045	0.155	3.94	
	2	13	0.092	0.407	10.34			5	17	0.052	0.147	3.73	
	2	12	0.105	0.395	10.03			5	16	0.061	0.139	3.53	
	2	11	0.117	0.382	9.70			5	15	0.070	0.130	3.30	
	2	10	0.130	0.370	9.40			5	14	0.060	0.120	3.05	
	2	9	0.145	0.355	9.02			5	13	0.092	0.107	2.72	
	2	8	0.160	0.340	8.64			6	25	0.020	0.146	3.71	
	2	7	0.175	0.325	8.25			6	24	0.022	0.144	3.66	
	2	6	0.190	0.310	7.87			6	23	0.025	0.141	3.58	
	2½	18	0.045	0.355	9.02			6	22	0.028	0.138	3.50	
	2½	17	0.052	0.347	8.81			6	21	0.031	0.135	3.43	
	2½	16	0.061	0.339	8.61			6	20	0.035	0.131	3.33	
	2½	15	0.070	0.330	8.38			6	19	0.040	0.126	3.20	f
	2½	14	0.080	0.320	8.13	t		6	18	0.045	0.121	3.07	
	2½	13	0.092	0.307	7.80			6	17	0.052	0.114	2.89	
	2½	12	0.105	0.295	7.49	r		6	16	0.061	0.105	2.67	r
	2½	11	0.117	0.282	7.16			6	15	0.070	0.096	2.44	
	2½	10	0.130	0.270	6.86			6	14	0.080	0.086	2.18	

f. Nearest approach to sizes of graded set, 1", ½", ¼", etc. *p.* Nearest size to punched screens, Table II. *t.* Sizes in Table. *r.* Rittinger's screens.

TABLE VII—*Continued.*

Mesh. (Meshes to the inch.)	Wire.		Space.		Reference.
	Trenton.	Diameter in Inches.	Inches.	Milli-meters.	
7	26	0.018	0.125	3.17	
7	25	0.020	0.123	3.12	
7	24	0.022	0.120	3.05	
7	23	0.025	0.118	3.00	
7	22	0.028	0.115	2.92	
7	21	0.031	0.112	2.84	t
7	20	0.035	0.108	2.74	
7	19	0.040	0.103	2.61	
7	18	0.045	0.098	2.49	
7	17	0.052	0.090	2.29	
7	16	0.061	0.082	2.08	
7	15	0.070	0.073	1.85	
8	27	0.017	0.108	2.74	
8	26	0.018	0.107	2.72	
8	25	0.020	0.105	2.67	
8	24	0.022	0.102	2.59	
8	23	0.025	0.100	2.54	
8	22	0.028	0.097	2.46	
8	21	0.031	0.094	2.39	
8	20	0.035	0.090	2.29	
8	19	0.040	0.085	2.16	
8	18	0.045	0.080	2.03	r
8	17	0.052	0.072	1.83	
8	16	0.061	0.064	1.62	
9	28	0.016	0.095	2.41	
9	27	0.017	0.094	2.39	
9	26	0.018	0.093	2.36	
9	25	0.020	0.091	2.31	
9	24	0.022	0.089	2.26	
9	23	0.025	0.086	2.18	
9	22	0.028	0.083	2.11	
9	21	0.031	0.080	2.03	t
9	20	0.035	0.076	1.93	
9	19	0.040	0.071	1.80	
9	18	0.045	0.066	1.68	
9	17	0.052	0.059	1.50	
10	29	0.015	0.085	2.16	
10	28	0.016	0.084	2.13	
10	27	0.017	0.083	2.11	
10	26	0.018	0.082	2.08	
10	25	0.020	0.080	2.03	
10	24	0.022	0.078	1.98	
10	23	0.025	0.075	1.90	
10	22	0.028	0.072	1.83	
10	21	0.031	0·069	1.75	
10	20	0.035	0.065	1.65	
10	19	0.040	0.060	1.52	
10	18	0.045	0.055	1.40	
12	30	0.014	0.069	1.75	
12	29	0.015	0.068	1.73	
12	28	0.016	0.067	1.70	
12	27	0.017	0.066	1.68	
12	26	0.018	0.065	1.65	
12	25	0.020	0.063	1.60	f
12	24	0.022	0.061	1.55	
12	23	0.025	0.058	1.47	p
12	22	0.028	0.055	1.40	rt
12	21	0.031	0.052	1.32	
12	20	0.035	0.048	1.22	
12	19	0.040	0.043	1.09	
14	34	0.010	0.061	1.55	
14	33	0.011	0.060	1.52	
14	32	0.012	0.059	1.50	
14	31	0.013	0.058	1.47	
14	30	0.014	0.057	1.45	
14	29	0.015	0.056	1.42	
14	28	0.016	0.055	1.40	
14	27	0.017	0.054	1.37	
14	26	0.018	0.053	1.35	
14	25	0.020	0.051	1.29	
14	24	0.022	0.049	1.24	p
14	23	0.025	0.046	1.17	
14	22	0.028	0.048	1.09	
14	21	0.031	0.040	1.02	
14	20	0.035	0.036	0.91	
16	35	0.009	0.053	1.35	
16	34	0.010	0.052	1.32	
16	33	0.011	0.051	1.29	
16	32	0.012	0.050	1.27	
16	31	0.013	0.049	1.24	
16	30	0.014	0.048	1.22	
16	29	0.015	0.047	1.19	
16	28	0.016	0.046	1.17	
16	27	0.017	0.045	1.14	
16	26	0.018	0.044	1.12	
16	25	0.020	0.042	1.07	r
16	24	0.022	0.040	1.02	t
16	23	0.025	0.037	0.94	
16	22	0.028	0.034	0.86	
16	21	0.031	0.031	0.79	
18	36	0.009	0.047	1.19	
18	35	0.0095	0.046	1.17	
18	34	0.010	0.045	1.14	
18	33	0.011	0.044	1.12	
18	32	0.012	0.043	1.09	
18	31	0.013	0.042	1.07	p
18	30	0.014	0.041	1.04	
18	29	0.015	0.040	1.02	
18	28	0.016	0.039	0.99	
18	27	0.017	0.038	0.96	
18	26	0.018	0.037	0.94	
18	25	0.020	0.035	0.89	
18	24	0.022	0.033	0.84	
18	23	0.025	0.030	0.76	
18	22	0.028	0.027	0.68	
20	36	0.009	0.041	1.04	
20	35	0.0095	0.040	1.03	
20	34	0.010	0.040	1.02	
20	33	0.011	0.039	0.99	
20	32	0.012	0.038	0.96	
20	31	0.013	0.037	0.94	
20	30	0.014	0.036	0.91	
20	29	0.015	0.035	0.89	p
20	28	0.016	0.034	0.86	
20	27	0.017	0.033	0.84	
20	26	0.018	0.032	0.81	
20	25	0.020	0.030	0.76	
20	24	0.022	0.027	0.68	
20	23	0.025	0.025	0.63	
22	36	0.009	0.038	0.97	
22	35	0.0095	0.038	0.96	
22	34	0.010	0.037	0.94	
22	33	0.011	0.036	0.91	
22	32	0.012	0.035	0.89	
22	31	0.013	0.034	0.86	
22	30	0.014	0.033	0.84	
22	29	0.015	0.032	0.81	
22	28	0.016	0.031	0.79	f
22	27	0.017	0.030	0.76	
22	26	0.018	0.029	0.74	
22	25	0.020	0.027	0.68	
22	24	0.022	0.025	0.63	
24	36	0.009	0.033	0.84	
24	35	0.0095	0.032	0.81	
24	34	0.010	0.032	0.80	
24	33	0.011	0.031	0.79	
24	32	0.012	0.030	0.76	
24	31	0.013	0.029	0.74	p
24	30	0.014	0.028	0.71	t
24	29	0.015	0.027	0.68	
24	28	0.016	0.026	0.66	r
24	27	0.017	0.025	0.63	
24	26	0.018	0.024	0.61	
24	25	0.020	0.022	0.56	

f. Nearest approach to sizes of graded set, 1″, ½″, ¼″, etc. *p.* Nearest size to punched screens, Table II. *t.* Sizes in Table. *r.* Rittinger's screens.

TABLE VII.—*Concluded.*

	Wire.		Space.				Wire.		Space.		
Mesh. Meshes to the inch.	Trenton.	Diameter in Inches.	Inches.	Milli-meters.	Reference.	Mesh. Meshes to the inch.	Trenton.	Diameter in Inches.	Inches.	Milli-meters.	Reference.
26	36	0.009	0.029	0.74		45	34	0.010	0.012	0.30	
26	35	0.0095	0.029	0.73		45	33	0.011	0.011	0.28	
26	34	0.010	0.028	0.71		45	32	0.012	0.010	0.25	
26	33	0.011	0.027	0.68	p	50	37	0.0085	0.011	0.29	
26	32	0.012	0.026	0.66		50	36	0.009	0.011	0.28	
26	31	0.013	0.025	0.63		50	35	0.0095	0.010	0.27	
26	30	0.014	0.024	0.61		50	34	0.010	0.010	0.25	rt
26	29	0.015	0.023	0.58		50	33	0.011	0.009	0.23	
26	28	0.016	0.022	0.56		50	32	0.012	0.008	0.20	
26	27	0.017	0.021	0.53		55	38	0.008	0.010	0.25	
26	26	0.018	0.020	0.51		55	37	0.0085	0.010	0.24	
28	36	0.009	0.027	0.68		55	36	0.009	0.009	0.23	
28	35	0.0095	0.026	0.67		55	35	0.0095	0.009	0.22	
28	34	0.010	0.026	0.66		55	34	0.010	0.008	0.20	
28	33	0.011	0.025	0.63		60	38	0.008	0.009	0.22	
28	32	0.012	0.024	0.61	p	60	37	0.0085	0.008	0.20	
28	31	0.013	0.023	0.58		60	36	0.009	0.008	0.19	f
28	30	0.014	0.022	0.56		60	35	0.0095	0.007	0.18	
28	29	0.015	0.021	0.53		60	34	0.010	0.007	0.16	
28	28	0.016	0.020	0.51		64	38	0.008	0.008	0.19	
28	27	0.017	0.018	0.48		64	37	0.0085	0.007	0.18	
30	36	0.009	0.024	0.62		64	36	0.009	0.007	0.17	t
30	35	0.0095	0.024	0.60		64	35	0.0095	0.006	0.16	
30	34	0.010	0.023	0.58		64	34	0.010	0.006	0.15	
30	33	0.011	0.022	0.56	p	70	39	0.0075	0.007	0.17	
30	32	0.012	0.021	0.53		70	38	0.008	0.006	0.15	r
30	31	0.013	0.020	0.51	tp	70	37	0.0085	0.006	0.14	
30	30	0.014	0.019	0.48		70	36	0.009	0.005	0.13	
30	29	0.015	0.018	0.46	p	70	35	0.0095	0.005	0.12	
30	28	0.016	0.017	0.43		74	39	0.0075	0.006	0.15	
35	36	0.009	0.019	0.50		74	38	0.0080	0.005	0.14	
35	35	0.0095	0.019	0.48		74	37	0.0085	0.005	0.13	
35	34	0.010	0.018	0.46		74	36	0.0090	0.004	0.12	
35	33	0.011	0.017	0.43	p	74	35	0.0095	0.004	0.10	
35	32	0.012	0.016	0.41		80	39	0.0075	0.005	0.13	
35	31	0.013	0.015	0.38	rpf	80	38	0.0080	0.004	0.12	t
35	30	0.014	0.014	0.35		80	37	0.0085	0.004	0.10	
35	29	0.015	0.013	0.33		80	36	0.0090	0.003	0.09	
40	37	0.0085	0.016	0.42		80	35	0.0095	0.003	0.08	
40	36	0.009	0.016	0.41		90	40	0.0070	0.004	0.10	
40	35	0.0095	0.015	0.40		90	39	0.0075	0.004	0.09	tf
40	34	0.010	0.015	0.38		90	38	0.0080	0.003	0.08	
40	33	0.011	0.014	0.35	tp	90	37	0.0085	0.003	0.07	
40	32	0.012	0.013	0.33		90	36	0.0090	0.002	0.05	
40	31	0.013	0.012	0.30		100	40	0.0070	0.003	0.08	
45	37	0.0085	0.014	0.35		100	39	0.0075	0.003	0.07	t
45	36	0.009	0.013	0.34		100	38	0.0080	0.002	0.05	
45	35	0.0095	0.013	0.32		100	37	0.0085	0.001	0.04	

f. Nearest approach to sizes of graded set, 1″, ½″, ¼″. etc. *p.* Nearest size to punched screens, Table II. *t.* Sizes in Table. *r.* Rittinger's screens.

SUBJECT TO REVISION.

[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

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BY E. J. MCCAUSTLAND, ITHACA, N. Y.

(London Meeting, July, 1906.)

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THE behavior of steel after overstrain and at moderate temperatures is fairly well known. It has been made the subject of much investigation, and our knowledge is clear and definite on many points. The ultimate raising of the elastic limit, after moderate overstrain, and the consequent lowering of the ductility, seem to be well established. It is also well understood that the immediate effect of overstrain is to lower the elastic limit, possibly to zero, but that if not interfered with, this limit will subsequently rise higher than before. The "tests after moderate temperature," reported in this paper, were undertaken to verify the above statements for the particular steel under investigation, and also to determine, if possible, the total time required for complete recovery from this state of overstrain.

The behavior of overstrained steel at temperatures at or below 32° F. is not so well known. Tests made by Prof. E. G. Coker, at McGill University,[1] show that steel, overstrained and subjected to cold, will remain in a state of overstrain for an indefinite period. I am not aware of any other published results of tests along this particular line.

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Johnson and W. F. Pond chose this subject for a thesis-investigation under my direction; and I am indebted to these gentlemen for much of the experimental data upon which this paper is based. Altogether, about 120 separate tests were made, of which only a few are here reported. As instructor, I was in close touch with the experimental work in all its stages, although the actual manipulation of the testing-apparatus was done by Messrs. Johnson and Pond. The experience gained in planning the tests of the previous two years was sufficiently extended and definite to permit the adoption of the following more satisfactory outline of procedure for the tests here reported:

This outline as planned, and with brief explanation, is given in full here for reference:—

Scheme of Experiments.

I. *Tests After Moderate Temperatures.*—Investigate the effect of time on the recovery of steel from overstrain, the specimen being subjected to moderate temperatures only,—*i. e.*, temperatures ranging from 60° to 70° F.

II. *Tests After High Temperatures.*—Investigate the accelerating effect of high temperature on the time of recovery of steel from overstrain (The high temperature referred to throughout this paper is that of saturated steam).

III. *Tests After Low Temperatures.*—Investigate the retarding effect of low temperatures,—*i. e.*, temperatures below 32° F., on the time of recovery of steel from overstrain.

IV. *Tests After Low-High and After Low-Moderate Temperatures.*—Investigate the effect of high and also of moderate temperatures on the recovery of overstrained steel which has been subjected for a considerable period to a low temperature.

Materials Used in These Tests.

Two kinds of steel were used in making these tests:

1. The grade known as "extra soft," the specimen being 2 in. wide and cut from a $\frac{5}{8}$ in. plate, thus giving a sectional area of 1.25 sq. in. The pieces were sheared wider than 2 in. and then milled down to gauge.

2. A mild steel, received in the form of $\frac{5}{8}$ in. round rods, which were not turned down at all, but were tested with the "skin" on. The area of these rods was taken as 0.312 sq. in.

Methods of Testing.

The general method followed in making these tests was the same for all the pieces tested. Measurements were taken to determine elongations on a gauge-length of 8 in., the extensometer apparatus being of the double micrometer screw type with electric contact, and reading directly to 0.001 in., and by estimation to 0.0001 in. This form of micrometer allows readings to be taken on opposite sides of the specimen, so that the mean of the readings gives the true relative deformations of the piece. To determine the stress-deformation relations, loads were applied, increasing by equal increments, and the micrometers were read at each loading, to determine the elongations. The load was occasionally reduced to zero, and the micrometers were read in order to determine the amount, if any, of the permanent elongation of the piece. In the accompanying tables, the loads are reduced to pounds per sq. in.; and the elongations determined from the micrometer-readings are reduced to inches per inch of length of specimen.

Cyclical Loadings.—When it was found that the elastic limit had been slightly exceeded, and a permanent stretch of from 0.03 to 0.06 in. in the 8-in. gauge-length had taken place, the load was entirely removed; the micrometers were reset to 8-in. gauge; and a second test was made with loads rising by equal increments up to a point slightly beyond the original elastic limit, and then returning by equal decrements to zero. So long as the specimen was in a state of overstrain, the plotting of the elongations for these cyclical loadings would form a so-called "hysteresis-loop," caused by the failure of the elastic forces within the piece to assert themselves promptly upon the removal of the external load. The width of these loops, under repeated loadings, would be reduced in proportion to the recovery from the state of overstrain. After the first cyclical loading, the bars were subjected to the temperature-conditions described for the separate tests, and the cyclical loadings were repeated at varying intervals in order to follow the process of recovery, or to demonstrate its acceleration or its complete arrest.

Temperature Conditions.

The "moderate" temperatures referred to throughout this paper are those usually prevailing in a room adjoining the laboratory, which varied from to 60° to 70° F. The "high" temperatures refer to those cases in which the specimen was subjected for 45 min. to a steam-bath in a copper boiler. The "low" temperatures were obtained by placing the specimens in one of the refrigerating-rooms near the laboratory. A record of the temperatures prevailing in this room throughout the period of these tests, shows that at no time did the thermometer register above 30° F. For purposes of testing, the specimens were transported to and from the cold-storage room in a small box packed with ice. During the tests, the temperature of the laboratory was kept as low as possible, by closing the doors and opening the windows to the outer air. Since all the tests after "low" temperatures were made during the winter, the highest temperature reached in the laboratory during these tests was 41° F. The specimens were kept packed in ice, except the ends, which were left free, until wedged in the testing-machine, the pack being removed just previously to the attachment of the micrometers. A cyclical test could ordinarily be run in about 30 min., so that the effect of any small rise in temperature during the test was of no practical importance.

Explanation of Tabulations and Curves.

In arranging the tables which follow, both for the stress-deformation tests and for the results of the cyclical loadings, an attempt has been made to condense the figures to the lowest possible limit consistent with completeness. The original record, or log of tests, included the total applied load and the two separate micrometer-readings. In these tables the loads have been reduced to pounds per sq. in., and only the mean of the simultaneous micrometer-readings is given. From these mean values the unit-elongations, included in the tables, have been computed, which indicate the amount of stretch, per in. of length, for the recorded load in pounds per sq. in. The manner in which the curves are drawn from the tabular values is obvious. The elastic limit of a specimen is determined from an inspection of the stress-deformation diagram. The total permanent stretch taking place in the gauge-length of 8 in. was determined for each specimen by a complete release of the load and an observation of the micrometer-readings. In tabulating the results of the cyclical loadings, a single column for the applied loads is made to serve for a number of tests, in order to save space on the printed page.

Discussion of Tests by Groups.

Moderate Temperatures.—About 40 tests were made on eight different specimens kept at moderate temperatures, and of these specimens, two of each kind of steel have been chosen as representing the typical behavior for these conditions. Specimens Nos. 1 and 2, although of the same kind of steel, differ somewhat in behavior. The ratio of deformation to stress above a load of 33,000 lb. is considerably greater in Specimen No. 2, notwithstanding the fact that it has a slightly higher elastic limit than Specimen No. 1. On occount of this fact, the cyclical loadings were not run up to such high values for No. 2 as for No. 1. While the tests on Specimen No. 1 did not extend beyond the 69-hr. period, it is to be noticed that although the recovery was practically complete, yet a slight difference in the elongations on the return-load may still be observed.

The curves for Specimens Nos. 3 and 4, of mild steel, agree more closely, notwithstanding the fact that the time of recovery is somewhat widely different. It is probable that the total stretch of No. 3, being considerably greater than that of No. 4, would operate to retard the time of complete recovery. A number of cyclical loadings, not included in the tables, were run on both these specimens. A comparison of the average times of recovery for the two kinds of steel shows that the mild steel recovers much more slowly than does the soft steel.

High Temperatures.—In this group, seven specimens were tested, a large number of observations being taken which are not here included. Specimens Nos. 5 and 6 were of the soft steel, and the sets of curves are very much alike. Attention is drawn to the differences in the form of loop No. 3 for the two specimens. In Specimen No. 5 the cycle marked No. 3 was taken immediately after the removal of the piece from the steam-bath, the temperature having been so reduced that the piece could be easily handled. In Specimen No. 6 the corresponding cycle was delayed for about an hour after the removal from the bath; and this delay resulted in the formation of a much narrower loop from the test.

Only two specimens of mild steel, Nos. 7 and 8, were tested for the effect of high temperature, and these results for both are given. It is very probable that the wide difference in the time of recovery of these two specimens was, in large measure, due to the difference in the maximum load attained in the respective cycles, which, although it amounted to only 700 lb. per sq. in., would have a comparatively large effect in the region of the elastic limit. The excess of permanent elongation in the case of Specimen No. 8 can scarcely be held accountable for any large part of this increase in the time required for complete recovery.

Low Temperatures.—In this group also, seven separate pieces were tested, and the results on four of the specimens are here given. The stress-deformation relations in Specimen No. 9, a piece of soft steel, were determined in the usual manner, and the test was followed at once by the cyclical loading, the curve for which is plotted as No. 2 on the diagram for this specimen. The piece was at once removed from the machine, packed in ice, and placed in cold storage, from which it was removed for a cyclical loading-test at intervals covering a period of 2,112 hours. Curve No. 5 indicates the condition of the piece after it had been at a freezing-temperature for this number of hours, and, in addition, had rested at a moderate temperature for a period of 24 hr. There is no indication whatever of recovery in this time. On the contrary, there seems to be a gradual widening of the loop throughout the whole period, which would indicate a gradual breaking down of the material. In all, 13 cycles were run on this piece, only seven of which are plotted on the diagram. Cycles plotted as curves No. 6, 7 and 8 were chosen at such time-intervals as would best show the slow but fairly uniform recovery of the material from a state of overstrain.

Specimen No. 10, a piece of soft steel, was tested in much the same manner as No. 9, but was left for a much longer period under the influence of low temperature. The piece was originally tested in April and remained in cold storage all summer, the final tests being made in November. Immediately after cycle No. 5 was taken, 4,728 hr. after the original test, the piece was placed in the laboratory at moderate temperature, and cycles were run at varying intervals of time to follow the process of recovery. Cycle No. 6, taken 120 hr. later, indicates an almost complete recovery of the elastic properties with a marked rise of the elastic limit. The figures from which cycle No. 6 was plotted are not given. It is to be noted that the time of recovery at moderate temperature of these specimens of extra soft steel, is about double the time required in the cases of those pieces which had not been subjected to the influence of low temperature for any time.

Specimen No. 11, a piece of mild steel, was tested in the same manner as Nos. 9 and 10, and was then subjected to low temperature, its condition after 2,708 hr. being indicated in the plot of cycle No. 4. The piece was then placed in a steam-bath for 45 min., after which it was left at moderate temperature. Its condition at the end of 24 hr. after the steam-bath, is indicated in curve No. 5; and the following curves show a gradual recovery until curve No. 8, taken 93 hr. later, when the process of recovery seems to be practically complete. This is the only piece of mild steel that was tested under these particular temperature-conditions; but the results obtained seem to be remarkably consistent among themselves.

Specimen No. 12, of soft steel, was subjected to the same treatment as No. 11, and at the end of a period of 2,111 hr., during which it had been subjected to .a temperature below 32° F., it showed little or no signs of recovery from the effects of the previous overstrain. The piece was then placed in a steam-bath for 45 min., and then left at moderate temperature for further tests. At the end of 24 hr. a cyclical loading test was made, the results of which are plotted in curve No. 5. This test showed that complete recovery had taken place. The more rapid recovery of this piece, as compared with that of the mild steel, Specimen No. 11, is very marked.

Summary of Tests and Conclusions.

Table I. gives a summary of the tests, so that the time of recovery from overstrain under different temperature-conditions, and for the two kinds of steel, may be appreciated at a glance.

An examination of Table I. shows clearly that all the tests, of which specimens Nos. 1 to 8 are types, exhibit results quite in harmony with those obtained by other experimenters along these lines. I am not aware of any tests which take into ac-

TABLE I.—*Summary of Tests.*

No.	Kind.	Elastic Limit.	Stretch in 8 Inches.	Hours of Freezing. Temp.	Time of Recovery.		Remarks.
					Moderate Temp.	After Steam Bath.	
		Lb. Sq. In.	Inches.				
1	Soft.	27,500	0.0339	None.	68		
2	Soft.	28,000	0.0366	None.	69		
3	Mild.	32,000	0.0632	None.	434	....	Increased time of recovery due to greater stretch.
4	Mild.	32,000	0.0372	None.	359		
5	Soft.	28,000	0.0517	None.	....	25	
6	Soft.	28,000	0.0512	None.	....	26	
7	Mild.	30,000	0.0129	None.	....	24	
8	Mild.	30,000	0.0147	None.	....	119	Increased time of recovery possibly due to higher cyclical loading.
9	Soft.	27,000	0.0244	2,112	142		
10	Soft.	27,500	0.0462	4,727	120		
11	Mild.	30,000	0.0206	2,707	....	93	
12	Soft.	28,500	0.0468	2,111	....	24	

count the variation in the carbon-content of the steel, as affecting the time of recovery from overstrain; but it appears from these experiments that recovery is more gradual as the carbon increases. Specimens Nos. 5 and 6, of soft steel, show in a marked degree the accelerating effect of high temperature on the time of recovery. Since only two tests, Specimens Nos. 7 and 8, were made on the mild steel, and since these show widely varying results as to time of recovery after the application of heat, it can be concluded only that high temperatures hasten recovery to a degree which remains uncertain without further tests. As to these particular pieces, it may be possible that the difference in time of recovery is due, to some extent at least, to the higher cyclical loading to which Specimen No. 8 was subjected.

With regard to the question upon which it was the object of these experiments to obtain light, the evidence appears conclusive that the effect of continued low temperature on a piece of steel which has been stretched slightly beyond the elastic limit, is to arrest completely the recovery of its elastic properties. That is, if the permanent elongation has not exceeded, say, 1 per cent., no recovery of elastic properties will take place while the specimen is kept at a temperature at or below 32° F. Maxwell,[2] in his article on "Constitution of Bodies," says: "We know that several substances, such as gutta-percha, india-rubber, etc., may be permanently stretched when cold, and yet, when afterwards heated to a certain temperature, they recover their original form." This appears to be true in the case of steel, provided the deformation has not been excessive. No difference can be appreciated in this regard between the two kinds of steel included in these tests. Nor does it appear that the possibility of a final recovery is at all interfered with by a long period of rest at a temperature below the 32° F. In the soft steel Specimens Nos. 9 and 10, it is true that the time required for recovery after the specimen was removed from the influence of the low temperature, was considerably greater than in the case of those specimens, Nos. 1 and 2, which had never been subjected to anything but moderate temperatures. In my opinion, however, this difference in the time of recovery was due, not to previous temperature-conditions, but rather to the differences in the percentages of elongation in the various specimens. As a final remark, having for its purpose the suggestion of an explanation of the foregoing phenomena, the closing paragraph of Prof. Maxwell's article, already cited, is pertinent:—

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[2] *Encyclopædia Britannica.*

> "This view of the constitution of a solid, as consisting of groups of molecules, some of which are in different circumstances from others, also helps to explain the state of the solid after a permanent deformation has been given to it. In this case some of the less stable groups have broken up and assumed new configurations, but it is quite possible that others, more stable, may still retain their original configurations, so that the form of the body is determined by the equilibrium between these two sets of groups; but if, on account of rise of temperature, increase of moisture, violent vibration, or any other cause, the breaking up of the less stable groups is facilitated, the more stable groups may again assert their sway and tend to restore the body to the shape it had before its deformation."

TABLE II.—*Stress-Deformation Tests—Extra Soft Steel.*

Section, $\frac{5}{8}$ in. by 2 in. Area, 1.25 sq. in. Measurement on 8-in. length.

	Specimen 1.			Specimen 2.		
Load, Lb. Per Sq. In.	Mean of Micrometer Readings (Inches.)	Elongation (Inches Per Inch).	Remarks.	Mean of Micrometer Readings (Inches).	Elongation (Inches Per Inch).	Remarks.
0	0.5479	0.00000		0.6505	0.00000	
3,200	0.5472	0.00009		0.6497	0.00010	
6,400	0.5461	0.00022		0.6490	0.00019	
9,600	0.5453	0.00032		0.6482	0.00029	
12,800	0.5443	0.00045		0.6474	0.00039	
16,000	0.5434	0.00057		0.6465	0.00050	
19,200	0.5424	0.00069		0.6457	0.00060	
22,400	0.5412	0.00084		0.6450	0.00070	
25,600	0.5394	0.00106	Elastic limit, 27,500 lb. per sq. in.	0.6441	0.00080	Elastic limit, 28,000 lb. per sq. in.
28,800	0.5372	0.00134		0.6419	0.00107	
29,600	0.5365	0.00142		0.6370	0.00170	
30,400	0.5345	0.00168		0.6190	0.00394	
31,200	0.5335	0.00180				
32,000	0.5315	0.00205				
32,800	0.5212	0.00334				
33,600	0.5048	0.00540	Permanent stretch in 8 in. = 8 by 0.00424 = 0.0339 in.			Permanent stretch in 8 in. = 8 by 0.00366 = 0.0293 in.
0	0.5140	0.00424		0.6212	0.00366	

Stress-Deformation Tests—Mild Steel.

Round rods. Diam., 0.63 in. Area, 0.312 sq. in.

	Specimen 3.			Specimen 4.		
Load, Lb. Per Sq. In.	Mean of Micrometer Readings (Inches).	Elongation (Inches Per Inch).	Remarks.	Mean of Micrometer Readings (Inches).	Elongation (Inches Per Inch).	Remarks.
0	0.5595	0.00000		0.5978	0.00000	
3,200	0.5585	0.00012		0.5963	0.00012	
6,400	0.5577	0.00022		0.5952	0.00026	
9,600	0.5568	0.00034		0.5944	0.00036	
12,800	0.5560	0.00044		0.5935	0.00047	
16,000	0.5550	0.00056		0.5926	0.00059	
19,200	0.5541	0.00067		0.5917	0.00070	
22,400	0.5533	0.00077		0.5909	0.00080	
25,600	0.5526	0.00086		0.5898	0.00094	
28,800	0.5516	0.00098		0.5887	0.00107	
30,400	No read	ing.		0.5882	0.00114	
32,000	0.5507	0.00110	Elastic limit, 32,000 lb. per sq. in.	0.5878	0.00125	Elastic limit, 32,000 lb. per sq. in.
33,600	0.5395	0.00250		0.5851	0.00152	
35,200	0.5288	0.00384		0.5825	0.00185	
36,800	0.4869	0.00907		0.5785	0.00235	
38,400	No read	ing.	Permanent stretch in 8 in. = 8 by 0.0079 = 0.0632 in.	0.5590	0.00480	Permanent stretch in 8 in. = 8 by 0.00465 = 0.00372 in.
0	0.4963	0.00790		0.5601	0.00465	

TABLE III.—*Cyclical Loading of Specimen 1—Extra Soft Steel.*

Section, ⅝ in. by 2 in. Area, 1.25 sq. in. Measurements on 8-in. length.

Load, Lb. Per Sq. In.	15 Minutes After Overstrain.		19 Hours After Overstrain.		68 Hours After Overstrain.	
	Mean of Micrometer Readings (Inches).	Elongation (Inches Per Inch).	Mean of Micrometer Readings (Inches).	Elongation (Inches Per Inch).	Mean of Micrometer Readings (Inches).	Elongation (Inches Per (Inch).
0	0.5140	0.00000	0.5124	0.00000	0.5425	0.00000
3,200	0.5132	0.00010	0.5116	0.00010	0.5414	0.00014
6,400	0.5123	0.00021	0.5107	0.00021	0.5407	0.00022
9,600	0.5113	0.00034	0.5101	0.00029	0.5400	0.00031
12,800	0.5103	0.00046	0.5092	0.00040	0.5392	0.00041
16,000	0.5096	0.00055	0.5083	0.00051	0.5384	0.00051
19,200	0.5086	0.00068	0.5075	0.00061	0.5376	0.00061
22,400	0.5076	0.00080	0.5066	0.00072	0.5366	0.00074
25,600	0.5069	0.00090	0.5056	0.00085	0.5360	0.00081
28,800	0.5056	0.00105	0.5046	0.00097	0.5352	0.00091
32,000	0.5043	0.00121	0.5035	0.00112	0.5340	0.00106
33,200	0.5036	0.00130	0.5028	0.00120	0.5337	0.00110
32,000	0.5033	0.00134	0.5031	0.00116	0.5340	0.00106
28,800	0.5040	0.00125	0.5038	0.00107	0.5349	0.00095
25,600	0.5050	0.00112	0.5046	0.00097	0.5355	0.00087
22,400	0.5061	0.00099	0.5056	0.00085	0.5365	0.00075
19,200	0.5070	0.00088	0.5065	0.00074	0.5372	0.00066
16,000	0.5076	0.00080	0.5073	0.00064	0.5382	0.00054
12,800	0.5086	0.00068	0.5083	0.00051	0.5389	0.00045
9,600	0.5100	0.00050	0.5091	0.00041	0.5399	0.00032
6,400	0.5108	0.00040	0.5102	0.00028	0.5406	0.00023
3,200	0.5118	0.00028	0.5111	0.00016	0.5414	0.00014
0	0.5126	0.00018	0.5119	0.00006	0.5425	0.00000

TABLE IV.—*Cyclical Loading of Specimen 2—Extra Soft Steel.*

Section, ⅝ in. by 2 in. Area, 1.25 sq. in. Measurements on 8 in. length.

Load, Lb. Per Sq. In.	15 Minutes After Overstrain.		18 Hours After Overstrain.		69 Hours After Overstrain.	
	Mean of Micrometer Readings (Inches).	Elongation (Inches Per Inch).	Mean of Micrometer Readings (Inches).	Elongation (Inches Per Inch).	Mean of Micrometer Readings (Inches).	Elongation (Inches per Inch).
0	0.6210	0.00000	0.6084	0.00000	0.5910	0.00000
3,200	0.6202	0.00010	0.6075	0.00011	0.5902	0.00010
6,400	0.6194	0.00020	0.6066	0.00022	0.5893	0.00021
9,600	0.6190	0.00025	0.6060	0.00030	0.5886	0.00030
12,800	0.6180	0.00038	0.6051	0.00041	0.5875	0.00044
16,000	0.6172	0.00048	0.6042	0.00052	0.5865	0.00056
19,200	0.6162	0.00060	0.6035	0.00061	0.5856	0.00067
22,400	0.6153	0.00071	0.6023	0.00076	0.5847	0.00079
25,600	0.6145	0.00081	0.6015	0.00086	0.5840	0.00088
27,200	0.6120	0.00112	0.6007	0.00097	0.5830	0.00100
25,600	0.6124	0.00107	0.6004	0.00100	0.5838	0.00090
22,400	0.6130	0.00100	0.6017	0.00084	0.5841	0.00080
19,200	0.6141	0.00086	0.6023	0.00076	0.5850	0.00075
16,000	0.6151	0.00074	0.6030	0.00067	0.5858	0.00065
12,800	0.6160	0.00062	0.6040	0.00055	0.5869	0.00051
9,600	0.6170	0.00050	0.6051	0.00041	0.5879	0.00038
6,400	0.6179	0.00039	0.6060	0.00030	0.5889	0.00026
3,200	0.6187	0.00029	0.6067	0.00021	0.5899	0.00013
0	0.6197	0.00016	0.6078	0.00008	0.5908	0.00002

TABLE V.—*Cyclical Loading of Specimen 3—Mild Steel.*

Diameter, 0.63 in. Area, 0.312 sq. in. Measurements on 8-in. length.

Load, Lb. Per Sq. In.	15 Minutes After Overstrain.		25 Hours After Overstrain.		48 Hours After Overstrain.		434 Hours After Overstrain.	
	Mean of Micrometer Readings (Inches).	Elongation (Inches Per Inch).	Mean of Micrometer Readings (Inches).	Elongation (Inches Per Inch).	Mean of Micrometer Readings (Inches).	Elongation (Inches Per Inch).	Mean of Micrometer Readings (Inches).	Elongation (Inches Per Inch).
0	0.4983	0.00005	0.4913	0.00000	0.4880	0.00000	0.4190	0.00000
3,200	0.4970	0.00016	0.4904	0.00011	0.4872	0.00100	....	....
6,400	0.4962	0.00026	0.4899	0.00018	0.4863	0.00021	0.4170	0.00025
9,600	0.4955	0.00035	0.4889	0.00030	0.4854	0.00032	....	....
12,800	0.4944	0.00049	0.4880	0.00041	0.4844	0.00045	0.4150	0.00050
16,000	0.4937	0.00057	0.4871	0.00052	0.4832	0.00060	....	....
19,200	0.4925	0.00072	0.4862	0.00064	0.4826	0.00067	0.4130	0.00075
22,400	0.4915	0.00085	0.4853	0.00075	0.4815	0.00081	....	....
25,600	0.4906	0.00096	0.4842	0.00090	0.4806	0.00092	0.4110	0.00100
28,800	0.4897	0.00107	0.4832	0.00101	0.4798	0.00102	....	....
32,000	0.4886	0.00121	0.4821	0.00115	0.4788	0.00115	0.4089	0.00126
35,200	0.4832	0.00190	0.4785	0.00160	0.4772	0.00135	0.4079	0.00139
32,000	0.4835	0.00185	0.4785	0.00160	0.4773	0.00134	0.4088	0.00127
28,800	0.4845	0.00172	0.4795	0.00147	0.4780	0.00125	....	.. ..
25;600	0.4852	0.00164	0.4804	0.00136	0.4785	0.00119	0.4108	0.00102
22,400	0.4862	0.00151	0.4814	0.00124	0.4799	0.00101	....	....
19,200	0.4871	0.00140	0.4819	0.00117	0.4806	0.00092	0.4127	0.00079
16,000	0.4882	0.00126	0.4831	0.00102	0.4819	0.00076	....	....
12,800	0.4889	0.00117	0.4840	0.00091	0.4826	0.00067	0.4147	0.00054
9,600	0.4900	0.00104	0.4851	0.00077	0.4835	0.00056	....	....
6,400	0.4910	0.00091	0.4865	0.00060	0.4843	0.00046	0.4165	0.00031
3,200	0.4920	0.00079	0.4875	0.00047	0.4855	0.00031	....	....
0	0.4928	0.00069	0.4879	0.00042	0.4862	0.00022	0.4188	0.00002

TABLE VI.—*Cyclical Loading of Specimen 4—Mild Steel.*

Diameter, 0.63 in. Area, 0.312 sq. in. Measurements on 8-in. length.

Load, Lb. Per Sq. In.	15 Minutes After Overstrain.		23 Hours After Overstrain.		47 Hours After Overstrain.		359 Hours After Overstrain.	
	Mean of Micrometer Readings (Inches).	Elongation (Inches Per Inch).	Mean of Micrometer Readings (Inches).	Elongation (Inches Per Inch).	Mean of Micrometer Readings (Inches).	Elongation (Inches Per Inch).	Mean of Micrometer Readings (Inches).	Elongation (Inches Per Inch).
0	0.5680	0.00000	0.5660	0.00000	0.5645	0.00000	0.5652	0.00000
3,200	0.5673	0.00009	0.5652	0.00010	0.5640	0.00006	....	....
6,400	0.5661	0.00023	0.5642	0.00022	0.5630	0.00019	0.5633	0.00024
9,600	0.5653	0.00034	0.5635	0.00031	0.5621	0.00030	....	....
12,800	0.5643	0.00046	0.5627	0.00041	0.5613	0.00040	0.5618	0.00042
16,000	0.5637	0.00054	0.5616	0.00055	0.5603	0.00052	....	....
19,200	0.5627	0.00066	0.5607	0.00066	0.5594	0.00064	0.5607	0.00056
22,400	0.5617	0.00079	0.5598	0.00077	0.5585	0.00075	....	....
25,600	0.5609	0.00089	0.5520	0.00087	0.5577	0.00085	0.5593	0.00074
28,800	0.5600	0.00100	0.5579	0.00101	0.5567	0.00097	....	....
32,000	0.5591	0.00111	0.5571	0.00111	0.5558	0.00109	0.5575	0.00097
35,200	0.5570	0.00137	0.5558	0.00128	0.5541	0.00130	0.5564	0.00110
32,000	0.5575	0.00131	0.5577	0.00129	0.5542	0.00129	0.5569	0.00103
28,800	0.5582	0.00122	0.5567	0.00116	0.5555	0.00112	....	....
25,600	0.5593	0.00109	0.5575	0.00106	0.5563	0.00102	0.5589	0.00079
22,400	0.5600	0.00100	0.5585	0.00094	0.5573	0.00090	....	....
19,200	0.5609	0.00089	0.5594	0.00082	0.5578	0.00084	0.5604	0.00060
16,000	0.5618	0.00077	0.5603	0.00071	0.5590	0.00069	....	....
12,800	0.5627	0.00066	0.5608	0.00065	0.5600	0.00056	0.5616	0.00045
9,600	0.5635	0.00056	0.5622	0.00047	0.5610	0.00044	....	....
6,400	0.5644	0.00045	0.5630	0.00037	0.5618	0.00034	0.5632	0.00025
3,200	0.5655	0.00031	0.5638	0.00027	0.5628	0.00021	....	....
0	0.5662	0.00022	0.5648	0.00015	0.5636	0.00011	0.5651	0.00001

TABLE VII.—*Stress-Deformation Tests—Extra Soft Steel.*

Section, ⅝ in. by 2 in. Area, 1.25 sq. in. Measurements on 8-in. length.

	Specimen 5.			Specimen 6.		
Load, Lb. Per Sq. In.	Mean of Micrometer Readings (Inches).	Elongation (Inches Per Inch).	Remarks.	Mean of Micrometer Readings (Inches).	Elongation (Inches Per Inch).	Remarks.
0	0.5744	0.00000		0.7079	0.00000	
3,200	0.5734	0.00012		0.7068	0.00014	
6,400	0.5728	0.00020		0.7061	0.00022	
9,600	0.5720	0.00030		0.7050	0.00036	
12,800	0.5715	0.00036		0.7043	0.00045	
16,000	0.5708	0.00045		0.7035	0.00055	
19,200	0.5701	0.00054		0.7028	0.00064	
22,400	0.5693	0.00064		0.7019	0.00075	
25,600	0.5683	0.00076		0.7010	0.00086	
27,200	0.5673	0.00089	Elastic limit, 28,000 lb. per	0.7000	0.00099	Elastic limit, 28,000 lb. per
28,800	0.5670	0.00092	sq. in.	0.6995	0.00105	sq. in.
30.400	0.5668	0.00101		0.6985	0.00117	
32.000	0.5645	0.00124		0.6975	0.00130	
32,800	0.5635	0.00136		0.6970	0.00136	
33,600	0.5618	0.00157		0.6954	0.00156	
35,200	0.5495	0.00310		0.6857	0.00277	
36,000	0.5408	0.00420		0.6477	0.00752	
36,800	0.4985	0.00950	Permanent stretch in 8 in.	No read	ing.	Permanent stretch in 8 in.
0	0.5227	0.00646	= 8 by 0.00646 = 0.0517 in.	0.6567	0.00640	= 8 by 0.00640 = 0.0512 in.

TABLE VIII.—*Stress-Deformation Tests—Mild Steel.*

Round rods. Diameter, 0.63 in. Area, 0.312 sq. in.

	Specimen 7.			Specimen 8.		
Load, Lb. Per Sq. In.	Mean of Micrometer Readings (Inches).	Elongation (Inches Per Inch).	Remarks.	Mean of Micrometer Readings (Inches).	Elongation (Inches Per Inch).	Remarks.
0	0.4899	0.00000		0.4695	0.00000	
3,200	0.4889	0.00012		0.4687	0.00010	
6,400	0.4876	0.00029		0.4676	0.00024	
9,600	0.4865	0.00042		0.4669	0.00032	
12,800	0.4853	0.00057		0.4660	0.00044	
16,000	0.4845	0.00067		0.4653	0.00052	
19,200	0.4835	0.00080		0.4646	0.00061	
22,400	0.4823	0.00095		0.4639	0.00070	
25,600	0.4810	0.00111		0.4629	0.00082	
28,800	0.4804	0.00119	Elastic limit, 30,000 lb. per	0.4621	0.00092	Elastic limit, 30,000 lb. per
30,400	0.4797	0.00127	sq. in.	0.4616	0.00099	sq. in.
32,000	0.4788	0.00139		0.4609	0.00107	
33,600	0.4771	0.00160		0.4594	0.00126	
35,200	0.4682	0.00271		0.4528	0.00209	
36,800	No read	ing.	Permanent stretch in 8 in.	0.4455	0.00300	Permanent stretch in 8 in.
0	0.4770	0.00161	= 8 by 0.00161 = 0.0129 in.	0.4548	0.00184	= 8 by 0.00184=0.0147 in.

TABLE IX.—*Cyclical Loading of Specimen 5—Extra Soft Steel.*

Section, ⅝ in. by 2 in. Area, 1.25 sq. in. Measurements on 8-in. length.

Load, Lb. Per Sq. In.	15 Minutes After Overstrain.		2 Hours After Overstrain, and 15 Minutes after Steam Bath of ¾ Hour.		25 Hours After Overstrain.	
	Mean of Micrometer Readings (Inches).	Elongation (Inches Per Inch).	Mean of Micrometer Readings (Inches).	Elongation (Inches Per Inch).	Mean of Micrometer Readings (Inches).	Elongation (Inches Per Inch).
0	0.5338	0.00000	0.5960	0.00000	0.5939	0.00000
3,200	0.5328	0.00012	0.5950	0.00013	0.5930	0.00011
6,400	0.5322	0.00020	0.5939	0.00026	0.5920	0.00024
9,600	0.5812	0.00032	0.5934	0.00033	0.5912	0.00034
12,800	0.5308	0.00044	0.5925	0.00044	0.5903	0.00045
16,000	0.5295	0.00054	0.5915	0.00056	0.5895	0.00055
19,200	0.5287	0.00064	0.5909	0.00064	0.5886	0.00066
22,400	0.5275	0.00079	0.5898	0.00078	0.5880	0.00074
25,600	0.5265	0.00091	0.5885	0.00094	0.5868	0.00089
28,800	0.5255	0.00104	0.5878	0.00103	0.5855	0.00104
32,200	0.5247	0.00114	0.5870	0.00113	0.5850	0.00111
35,000	0.5233	0.00131	0.5846	0.00142	0.5841	0.00122
32,000	0.5234	0.00130	0.5855	0.00131	0.5848	0.00114
28,800	0.5242	0.00120	0.5860	0.00125	0.5854	0.00106
25,600	0.5250	0.00110	0.5869	0.00118	0.5867	0.00090
22,400	0.5257	0.00101	0.5877	0.00103	0.5881	0.00072
19,200	0.5270	0.00085	0.5888	0.00090	0.5886	0.00066
16,000	0.5277	0.00076	0.5898	0.00077	0.5896	0.00054
12,800	0.5284	0.00067	0.5914	0.00057	0.5902	0.00046
9,600	0.5297	0.00051	0.5919	0.00051	0.5910	0.00036
6,400	0.5305	0.00041	0.5926	0.00042	0.5920	0.00024
3,200	0.5313	0.00031	0.5935	0.00031	0.5930	0.00011
0	0.5320	0.00023	0.5945	0.00019	0.5940	0.00000

TABLE X.—*Cyclical Loading of Specimen 6—Extra Soft Steel.*

Section, ⅝ in. by 2 in. Area, 1.25 sq. in. Measurements on 8-in. length.

Load, Lb. Per Sq. In.	15 Minutes After Overstrain.		3 Hours After Overstrain, and 1 Hour after Steam Bath of ¾ Hour.		26 Hours After Overstrain.	
	Mean of Micrometer Readings (Inches).	Elongation (Inches Per Inch).	Mean of Micrometer Readings (Inches).	Elongation (Inches Per Inch).	Mean of Micrometer Readings (Inches).	Elongation (Inches Per Inch).
0	0.6574	0.00000	0.6457	0.00000	0.6453	0.00000
3,200	0.6565	0.00011	0.6446	0.00014	0.6446	0.00009
6,400	0.6553	0.00026	0.6439	0.00022	0.6436	0.00021
9,600	0.6547	0.00034	0.6430	0.00034	0.6428	0.00031
12,800	0.6539	0.00044	0.6422	0.00044	0.6421	0.00046
16,000	0.6531	0.00054	0.6412	0.00056	0.6413	0.00050
19,200	0.6520	0.00067	0.6404	0.00066	0.6405	0.00060
22,400	0.6510	0.00080	0.6397	0.00075	0.6395	0.00072
25,600	0.6502	0.00090	0.6388	0.00086	0.6388	0.00081
28,800	0.6493	0.00101	0.6378	0.00098	0.6378	0.00094
32,000	0.6480	0.00117	0.6371	0.00107	0.6372	0.00101
35,000	0.6460	0.00142	0.6361	0.00120	0.6363	0.00112
32,200	0.6460	0.00142	0.6370	0.00109	0.6378	0.00100
28,800	0.6466	0.00135	0.6373	0.00105	0.6379	0.00092
25,600	0.6478	0.00120	0.6382	0.00094	0.6389	0.00080
22,400	0.6486	0.00110	0.6390	0.00084	0.6396	0.00071
19,200	0.6494	0.00100	0.6400	0.00071	0.6405	0.00060
16,000	0.6501	0.00091	0.6407	0.00062	0.6412	0.00051
12,800	0.6512	0.00077	0.6015	0.00052	0.6422	0.00039
9,600	0.6522	0.00065	0.6423	0.00042	0.6429	0.00030
6,400	0.6531	0.00054	0.6432	0.00031	0.6437	0.00020
3,200	0.6540	0.00042	0.6440	0.00021	0.6446	0.00009
0	0.6549	0.00031	0.6447	0.00012	0.6453	0.00000

TABLE XI.—*Cyclical Loading of Specimen 7—Mild Steel.*

Round rod. Diam., 0.63 in. Area, 0.312 sq. in. Measurements on 8-in length.

Load, Lb. Per Sq. In.	15 Minutes After Overstrain.		2 Hours After Overstrain, and ⅛ Hour after Steam Bath of ¾ Hour.		24 Hours After Overstrain.	
	Mean of Micrometer Readings (Inches).	Elongation (Inches Per Inch).	Mean of Micrometer Readings (Inches).	Elongation (Inches Per Inch).	Mean of Micrometer Readings (Inches).	Elongation (Inches Per Inch).
0	0.4772	0.00000	0.4481	0.00000	0.4470	0.00000
6,400	0.4755	0.00021	0.4460	0.00026	0.4452	0.00022
12,800	0.4735	0.00046	0.4447	0.00042	0.4435	0.00044
19,200	0.4721	0.00064	0.4431	0.00062	0.4416	0.00067
25,600	0.4702	0.00087	0.4418	0.00079	0.4400	0.00087
32,000	0.4685	0.00109	0.4396	0.00106	0.4385	0.00106
34,500	0.4662	0.00137	0.4383	0.00122	0.4379	0.00114
32,000	0.4659	0.00141	0.4388	0.00116	0.4384	0.00107
25,600	0.4577	0.00119	0.4407	0.00092	0.4400	0.00087
19,200	0.4695	0.00096	0.4428	0.00072	0.4415	0.00069
12,800	0.4710	0.00077	0.4441	0.00050	0.4434	0.00045
6,400	0.4726	0.00057	0.4455	0.00032	0.4450	0.00025
0	0.4748	0.00080	0.4468	0.00016	0.4470	0.00000

TABLE XII.—*Cyclical Loading of Specimen 8—Mild Steel.*

Round rod. Diam., 0.63 in. Area, 0.312 sq. in. Measurements on 8-in. length.

Load, Lb. Per Sq. In.	15 Minutes After Overstrain.		24 Hours After Overstrain.		49 Hours After Overstrain.		119 Hours After Overstrain.	
	Mean of Micrometer Readings (Inches).	Elongation (Inches Per Inch).	Mean of Micrometer Readings (Inches).	Elongation (Inches Per Inch).	Mean of Micrometer Readings (Inches).	Elongation (Inches Per Inch).	Mean of Micrometer Readings (Inches).	Elongation (Inches Per Inch).
3,200	0.4550	0.00000	0.4520	0.00000	0.4480	0.00000	0.4430	0.00000
6,400	0.5430	0.00025	0.4497	0.00029	0.4460	0.00025	0.4411	0.00024
12,800	0.4513	0.00046	0.4482	0.00047	0.4442	0.00047	0.4392	0.00048
19,200	0.4497	0.00066	0.4464	0.00070	0.4425	0.00069	0.4377	0.00066
25,600	0.4480	0.00087	0.4449	0.00089	0.4410	0.00087	0.4360	0.00088
32,000	0.4459	0.00114	0.4430	0.00112	0.4392	0.00110	0.4344	0.00108
35,200	0.4442	0.00135	0.4407	0.00141	0.4367	0.00141	0.4332	0.00122
32,000	0.4446	0.00130	0.4408	0.00140	0.4371	0.00136	0.4342	0.00110
25,600	0.4461	0.00111	0.4425	0.00119	0.4387	0.00116	0.4358	0.00090
19,200	0.4480	0.00087	0.4442	0.00097	0.4402	0.00097	0.4376	0.00067
12,800	0.4495	0.00069	0.4457	0.00079	0.4422	0.00072	0.4390	0.00050
6,400	0.4516	0.00042	0.4475	0.00056	0.4437	0.00054	0.4409	0.00026
0	0.4536	0.00017	0.4497	0.00029	0.4459	0.00026	0.4428	0.00002

TABLE XIII.—*Cyclical Loading of Specimen 9—Extra Soft Steel.*

Section, ⅜ in. by 2 in. Area, 1.25 sq. in. Measurements on 8-in. length.

Load, Lb. Per Sq. In.	15 Minutes After Overstrain.		48 Hours After Overstrain, and 47 Hours at Freezing.		2092 Hours After Overstrain, and 2091 Hours at Freezing.		2136 Hours After Overstrain, 2112 at Freezing and 24 Hours at Moderate.	
	Mean of Micrometer Readings (Inches).	Elongation (Inches Per Inch).	Mean of Micrometer Readings (Inches).	Elongation (Inches Per Inch).	Mean of Micrometer Readings (Inches).	Elongation (Inches Per Inch).	Mean of Micrometer Readings (Inches).	Elongation (Inches Per Inch).
0	0.5709	0.00000	0.5252	0.00000	0.5127	0.00000	0.4990	0.00000
3,200	0.5700	0.00011	0.5244	0.00010	0.5117	0.00012	0.4980	0.00012
6,400	0.5689	0.00025	0.5235	0.00021	0.5106	0.00026	0.4971	0.00024
9,600	0.5682	0.00034	0.5227	0.00031	0.5097	0.00037	0.4967	0.00029
12,800	0.5672	0.00046	0.5220	0.00040	0.5090	0.00046	0.4952	0.00047
16,000	0.5665	0.00055	0.5207	0.00056	0.5077	0.00062	0.4946	0.00055
19,200	0.5658	0.00064	0.5200	0.00065	0.5066	0.00076	0.4940	0.00062
22,400	0.5649	0.00075	0.5194	0.00072	0.5058	0.00086	0.4932	0.00072
25.600	0.5638	0.00089	0.5184	0.00085	0.5046	0.00101	0.4914	0.00095
28,800	0.5595	0.00142	0.5135	0.00146	0.4984	0.00179	9.4845	0.00181
25,600	0.5596	0.00141	0.5135	0.00146	0.4982	0.00181	0.4846	0.00180
22,400	0.5600	0.00136	0.5143	0.00136	0.4890	0.00171	0.4853	0.00171
19,200	0.5610	0.00124	0.5146	0.00132	0.4997	0.00162	0.4860	0.00162
16,000	0.5621	0.00110	0.5156	0.00120	0.5005	0.00152	0.4865	0.00156
12,800	0.5631	0.00097	0.5165	0.00109	0.5014	0.00141	0.4872	0.00147
9,600	0.5639	0.00087	0.5172	0.00100	0.5023	0.00130	0.4886	0.00130
6,400	0.5647	0.00077	0.5180	0.00091	0.5031	0.00120	0.4891	0.00124
3,200	0.5659	0.00062	0.5189	0.00079	0.5042	0.09106	0.4899	0.00114
0	0.5669	0.00050	0.5202	0.00062	0.5050	0.00096	0.4911	0.00098

	2183 Hours After Overstrain, 2112 at Freezing and 71 at Moderate.		2231 Hours After Overstrain, 2112 at Freezing and 119 at Moderate.		2254 Hours After Overstrain, 2112 at Freezing and 142 at Moderate.	
0	0.4923	0.00000	0.6111	0.00000	0.6085	0.00000
3,200	0.4911	0.00015	0.6104	0.00009	0.6075	0.00012
6,400	0.4901	0.00028	0.6095	0.00020	0.6067	0.00022
9,600	0.4892	0.00039	0.6085	0.00033	0.6058	0.00034
12,800	0.4883	0.00050	0.6080	0.00039	0.6050	0.00044
16,000	0.4872	0.00064	0.6069	0.00052	0.6045	0.00050
19,200	0.4868	0.00069	0.6060	0.00064	0.6035	0.00062
22,400	0.4855	0.00085	0.6052	0.00074	0.6025	0.00075
25,600	0.4851	0.00090	0.6045	0.00083	0.6017	0.00085
28,800	0.4835	0.00110	0.6029	0.00102	0.6002	0.00104
25,600	0.4836	0.00109	0.6030	0.00101	0.6017	0.00085
22,400	0.4846	0.00096	0.6036	0.00094	0.6021	0.00080
19,200	0.4855	0.00085	0.6045	0.00082	0.6031	0.00067
16,000	0.4863	0.00075	0.6054	0.00071	0.6040	0.00056
12,800	0.4870	0.00066	0.6061	0.00062	0.6050	0.00044
9,600	0.4880	0.00054	0.6070	0.00051	0.6059	0.00032
6,400	0.4888	0.00044	0.6082	0.00036	.06065	0.00025
3,200	0.4895	0.00035	0.6089	0.00028	0.6074	0.00014
0	0.4905	0.00022	0.6096	0.00019	0.6085	0.00000

TABLE XIV.—*Stress-Deformation Tests—Extra Soft Steel.*

Section ⅝ in. by 2 in. Area, 1.25 sq. in. Measurement on 8-in. length.

	Specimen 9.			Specimen 10.		
Load, Lb. Per Sq. In.	Mean of Micrometer Readings (Inches).	Elongation (Inches Per Inch).	Remarks.	Mean of Micrometer Readings (Inches).	Elongation (Inches Per Inch).	Remarks.
0	0.5946	0.00000		0.9733	0.00000	
3,200	0.5938	0.00010		0.9729	0.00005	
6,400	0.5930	0.00020		0.9721	0.00015	
9,600	0.5921	0.00031		0.9708	0.00031	
12,800	0.5910	0.00045		0.9705	0.00035	
16,000	0.5905	0.00051		0.9693	0.00050	
19,200	0.5895	0.00064		0.9684	0.00061	
22,400	0.5882	0.00080		0.9670	0.00079	
24,000	0.5878	0.00085		0.9668	0.00085	
25,600	0.5875	0.00089		0.9658	0.00094	
26,400	0.5870	0.00095	Elastic limit, 27,000 lb. per sq. in.	No read	ing.	Elastic limit, 27,500 lb. per sq. in.
27,200	0.5865	0.00101		0.9648	0.00106	
28,000	0.5863	0.00104		No read	ing.	
28,800	0.5801	0.00181		0.9637	0.00120	
29,600	0.5757	0.00236		No read	ing.	
30,000	0.5642	0.00380		No read	ing.	
32,000	No read	ing.		0.9532	0.00251	
35,200	No read	ing.	Permanent stretch in 8 in. =8 by 0.00305=0.0244 in.	0.9174	0.00698	Permanent stretch in 8 in. =8 by 0.00577=0.0462 in.
0	0.5702	0.00305		0.9271	0.00577	

TABLE XV.—*Cyclical Loading of Specimen* 10—*Extra Soft Steel.*

Section, ⅝ in. by 2 in. Area, 1.25 sq. in. Measurements on 8-in. length.

	24 Hours After Overstrain, 23 at Freezing.		168 Hours After Overstrain, 167 at Freezing.		361 Hours After Overstrain, 360 at Freezing.		4728 Hours After Overstrain, 4727 at Freezing.	
Load, Lb. Per Sq. In.	Mean of Micrometer Readings (Inches).	Elongation (Inches Per Inch).	Mean of Micrometer Readings (Inches).	Elongation (Inches Per Inch).	Mean of Micrometer Readings (Inches).	Elongation (Inches Per Inch).	Mean of Micrometer Readings (Inches).	Elongation (Inches Per Inch).
0	0.0320	0.00000	0.0165	0.00000	0.0053	0.00000	0.5968	0.00000
3,200	0.0331	0.00014	0.0178	0.00016	0.0061	0.00010	0.5958	0.00012
6,400	0.0340	0.00025	0.0185	0.00025	0.0071	0.00022	0.5947	0.00026
9,600	0.0352	0.00040	0.0196	0.00039	0.0081	0.00035	0.5937	0.00039
12,800	0.0362	0.00052	0.0206	0.00051	0.0090	0.00046	0.5928	0.00050
16,000	0.0372	0.00065	0.0215	0.00062	0.0102	0.00061	0.5919	0.00061
19,200	0.0382	0.00077	0.0228	0.00079	0.0105	0.00065	0.5909	0.00074
22,400	0.0391	0.00089	0.0233	0.00085	0.0116	0.00079	0.5901	0.00084
25,600	0.0400	0.00100	0.0243	0.00097	0.0126	0.00091	0.5892	0.00095
28,800	0.0412	0.00115	0.0254	0.00111	0.0137	0.00105	0.5884	0.00105
32,000	0.0425	0.00131	0.0270	0.00131	0.0149	0.00120	0.5870	0.00122
28,800	0.0417	0.00121	0.0258	0.00116	0.0142	0.00111	0.5879	0.00111
25,600	0.0408	0.00110	0.0248	0.00104	0.0135	0.00102	0.5887	0.00101
22,400	0.0399	0.00099	0.0238	0.00091	0.0126	0.00091	0.5895	0.00091
19,200	0.0390	0.00087	0.0234	0.00086	0.0117	0.00080	0.5902	0·00082
16,000	0.0381	0.00076	0.0223	0.00072	0.0108	0.00069	0.5914	0.00067
12,800	0.0373	0.00066	0.0213	0.00060	0.0101	0.00060	0.5921	0.00059
9,600	0.0363	0.00054	0.0204	0.00049	0.0090	0.00046	0.5927	0.00051
6,400	0.0353	0.00041	0.0194	0.00036	0.0081	0.00035	0.5940	0.00035
3,200	0.0344	0.00030	0.0185	0.00025	0.0072	0.00024	0.5949	0.00024
0	0.0335	0.00019	0.0178	0.00016	0.0064	0.00014	0.5957	0.00014

TABLE XVI.—*Stress-Deformation Tests.*

Specimen 11, round rod, diam., 0.63 in. Area, 0.312 sq. in. Mild steel. — **Specimen 12, ⅝ in. by 2 in. Area, 1.25 sq. in. Extra soft steel.**

Load, Lb. Per Sq. In.	Mean of Micrometer Readings (Inches).	Elongation (Inches Per Inch).	Remarks.	Mean of Micrometer Readings (Inches).	Elongation (Inches Per Inch).	Remarks
0	0.5964	0.00000		0.5225	0.00000	
3,200	0.5955	0.00011		0.5216	0.00011	
6,400	0.5947	0.00021		0.5207	0.00022	
9,600	0.5940	0.00030		0.5195	0.00037	
12,800	0.5932	0.00040		0.5184	0.00051	
16,000	0.5925	0.00049		0.5180	0.00056	
19,200	0.5911	0.00066		0.5170	0.00069	
22,400	0.5904	0.00075		0.5162	0.00079	
25,600	0.5892	0.00090		0.5151	0.00092	
27,200	No read	ing.		0.5148	0.00096	
28,800	0.5884	0.00100	Elastic limit, 30,000 lb. per sq. in.	0.5144	0.00101	Elastic limit, 28,500 lb. per sq. in.
30,400	0.5880	0.00105		0.5139	0.00107	
32,000	0.5875	0.00111		0.5129	0.00120	
32,800	No read	ing.		0.5095	0.00162	
33,600	0.5865	0.00124		0.4675	0.00687	
35,200	0.5829	0.00167		No read	ing.	
36,800	0.5667	0.00371	Permanent stretch in 8 in. = 8 by 0.00257 = 0.0206 in.	No read	ing.	Permanent stretch in 8 in. = 8 by 0.00585 = 0.0468 in.
0	0.5758	0.00257		0.4757	0.00585	

TABLE XVII.—*Cyclical Loading of Specimen* 11—*Mild Steel.*

Round rod, 0.63 in. in diam. Area, 0.312 sq. in. Measurements on 8-in. length.

Load, Lb. Per Sq. In.	15 Minutes After Overstrain.		73 Hours After Overstrain, and 72 Hours at Freezing.		2708 Hours After Overstrain, and 2707 Hours at Freezing.		2782 Hours After Overstrain, 2708 at Freezing, 24 at Moderate After Steam Bath.	
	Mean of Micrometer Readings (Inches).	Elongation (Inches Per Inch).	Mean of Micrometer Readings (Inches).	Elongation (Inches Per Inch).	Mean of Micrometer Readings (Inches).	Elongation (Inches Per Inch).	Mean of Micrometer Readings (Inches).	Elongation (Inches Per Inch).
0	0.5767	0.00000	0.4904	0.00000	0.5851	0.00000	0.5771	0.00000
6,400	0.5748	0.00024	0.4885	0.00024	0.5828	0.00029	0.5748	0.00029
12,800	0.5729	0.00047	0.4864	0.00050	0.5811	0.00050	0.5735	0.00045
19,200	0.5714	0.00066	0.4842	0.00077	0.5790	0.00076	0.5716	0.00069
25,600	0.5696	0.00089	0.4816	0.00110	0.5768	0.00104	0.5692	0.00099
32,000	0.5675	0.00115	0.4785	0.00149	0.5746	0.00131	0.5652	0.00149
35,200	0.5632	0.00169	0.4763	0.00176	0.5725	0.00158	0.5647	0.00155
32,000	0.5645	0.00152	0.4768	0.00170	0.5730	0.00151	0.5647	0.00155
25,600	0.5657	0.00137	0.4785	0.00149	0.5746	0.00131	0.5664	0.00134
19,200	0.5675	0.00115	0.4802	0.00127	0.5756	0.00119	0.5682	0.00111
12,800	0.5693	0.00092	0.4820	0.00105	0.5772	0.00099	0.5706	0.00081
6,400	0.5709	0.00072	0.4885	0.00086	0.5787	0.00080	0.5723	0.00060
0	0.5728	0.00049	0.4856	0.00060	0.5795	0.00070	0.5747	0.00030

	2754 Hours After Overstrain, 2708 at Freezing and 46 at Moderate After Steam Bath.		2778 Hours After Overstrain, 2708 at Freezing and 70 at Moderate After Steam Bath.		2801 Hours After Overstrain, 2708 at Freezing and 93 at Moderate After Steam Bath.			
0	0.5694	0.00000	0.5669	0.00000	0.5650	0.00000		
6,400	0.5670	0.00030	0.5651	0.00022	0.5631	0.00024		
12,800	0.5652	0.00052	0.5634	0.00044	0.5616	0.00042		
19,200	0.5633	0.00076	0.5616	0.00066	0.5598	0.00065		
25,600	0.5615	0.00099	0.5599	0.00087	0.5580	0.00087		
32,000	0.5596	0·00122	0.5580	0.00111	0.5562	0.00110		
35,200	0.5580	0.00142	0.5559	0.00137	0.5550	0.00125		
32,000	0.5584	0.00137	0.5565	0.00130	0.5560	0.00112		
25,600	0.5601	0.00116	0.5580	0.00111	0.5579	0.00089		
19,200	0.5620	0.00092	0.5600	0.00086	0.5598	0.00071		
12,800	0.5640	0.00067	0.5617	0.00065	0.5613	0.00046		
6,400	0.5657	0.00046	0.5635	0.00042	0.5631	0.00024		
0	0.5681	0.00016	0.5658	0.00014	0.5650	0.00000		

TABLE XVIII.—*Cyclical Loading of Specimen 12—Extra Soft Steel.*

Section, ⅝ in. by 2 in. Area, 1.25 sq. in. Measurements on 8-in. length.

	15 Minutes After Overstrain.		71 Hours After Overstrain, 70 Hours Freezing.		2112 Hours After Overstrain, 2111 at Freezing.		2135 Hours After Overstrain, 2111 at Freezing, 24 at Moderate After Steam Bath.	
Load, Lb. Per Sq. In.	Mean of Micrometer Readings (Inches).	Elongation (Inches Per Inch).	Mean of Micrometer Readings (Inches).	Elongation (Inches Per Inch).	Mean of Micrometer Readings (Inches).	Elongation (Inches Per Inch).	Mean of Micrometer Readings (Inches).	Elongation (Inches Per Inch).
0	0.5760	0.00000	0.4932	0.00000	0.4965	0.00000	0.5288	0.00000
3,200	0.5752	0.00010	0.4926	0.00007	0.4953	0.00015	0.5278	0.00012
6,400	0.5737	0.00029	0.4917	0.00019	0.4942	0.00029	0.5271	0.00021
9,600	0.5735	0.00031	0.4905	0.00034	0.4935	0.00038	0.5262	0.00032
12,800	0.5727	0.00041	0.4896	0.00045	0.4924	0.00051	0.5257	0.00039
16,000	0.5715	0.00056	0.4889	0.00054	0.4914	0.00064	0.5246	0.00052
19,200	0.5709	0.00064	0.4875	0.00071	0.4905	0.00075	0.5238	0.00062
22,400	0.5700	0.00075	0.4867	0.00081	0.4891	0.00092	0.5232	0.00070
25,600	0.5690	0.00087	0.4855	0.00096	0.4885	0.00100	0.5217	0.00089
28,800	0.5681	0.00099	0.4844	0.00110	0.4877	0.00110	0.5214	0.00092
32,000	0.5659	0.00126	0.4821	0.00140	0.4868	0.00121	0.5207	0.00101
28,800	0.5660	0.00125	0.4827	0.00131	0.4874	0.00114	0.5212	0.00095
25,600	0.5674	0.00107	0.4836	0.00120	0.4884	0.00101	0.5225	0.00079
22,400	0.5682	0.00097	0.4845	0.00109	0.4886	0.00099	0.5231	0.00071
19,200	0.5692	0.00085	0.4855	0.00096	0.4895	0.00087	0.5237	0.00064
16,000	0.5698	0.00077	0.4862	0.00087	0.4902	0.00079	0.5245	0.00054
12,800	0.5705	0.00069	0.4874	0.00072	0.4914	0.00064	0.5256	0.00040
9,600	0.5717	0.00054	0.4884	0.00060	0.4925	0.00050	0.5260	0.00035
6,400	0.5726	0.00042	0.4895	0.00046	0.4933	0.00040	0.5270	0.00022
3,200	0.5739	0.00026	0.4902	0.00037	0.4934	0.00039	0.5277	0.00014
0	0.5741	0.00024	0.4913	0.00024	0.4950	0.00019	0.5287	0.00001

SUBJECT TO REVISION.

[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

The Amalgamation of Gold-Ores.*

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(London Meeting, July, 1906.)

The purpose of the following research, as originally planned, was to investigate the influence of temperature upon the plate-amalgamation process. In order to consider the amalgamation process intelligently, it was first necessary to learn the nature of an amalgam. In the performance of this task it was found necessary to consult a large volume of literature and to perform experimental investigations. The conceptions of the nature of amalgams thus obtained have so important a bearing on the amalgamation-process as a whole, as well as upon the possible influences of temperature, that it was advisable to include them in the treatment of the subject. The broader title is therefore used, even though some features of the amalgamation process have been treated very briefly and others entirely omitted, there being nothing new to present regarding them and their development not required for a clear presentation of the matter in hand.

I. HISTORICAL INTRODUCTION.

Gold was one of the earliest metals known to man. Occurring in the metallic state, it could be picked up in nuggets or washed, as gold dust, from the sand and gravel of streams. Interesting descriptions of the processes employed in early times for the recovery of gold may be found in Pliny's *Natural History* and in the treatise by Agricola on ores and minerals. But little progress in the treatment of the ores of gold was possible until efficient crushing machines were devised. This want was supplied by the introduction, about the beginning of the sixteenth century, of the stamp mill to treat the ores of Saxony. Blanket strakes, or similar devices, were used to catch the gold. Except in the gradual improvement of the machinery no important advances were made for many years. Hungary was the principal center of gold milling in the eighteenth century. When the gold-fields of the southern United States were discovered the processes used there were substantially the same as those employed in Hungary. But when the gold-fields of California were discovered the great richness of the ores naturally stimulated inventive ability and a legion of patent amalgamators resulted; these mostly survive at present only in the Patent Office records.

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An improvement of lasting merit was the substitution of copper plates "amalgamated" or coated with a film of mercury, for the blanket-strakes, etc., until then employed to catch the gold liberated by crushing. This improvement is of such signal importance that it is to be regretted that the inventor is not known. The introduction of amalgamated plates into all the districts where gold-ores were being milled quickly followed, until at present their use is well-nigh universal for ores that are adapted to stamp-milling or dredging.

II. The Amalgams.

The amalgams have been a subject for research since the earliest days of the alchemists, and in few directions has so much work been done with such meager results in the acquiring of exact information. Research has proceeded along every practicable line, but it is not yet possible to say that the nature of amalgams is completely understood, although results obtained within the last few years have placed them in a much clearer light than ever before.

The assumption was early made that mercury forms an inter-metallic compound, or a series of compounds, with the metals with which it amalgamates. Many attempts have been made to isolate such compounds by the use of solvents, pressure, filtering, or volatilization, and many compounds have been described, although the most accurate work has shown in many cases that the results are not concordant enough to justify the assigning of definite formulæ. The heat of formation of amalgams also has been studied by several investigators, most notably Berthelot. It was found that in some cases heat was evolved and in others absorbed. A simple and complete explanation of the results was not easy in most cases. The specific gravity and specific heat of amalgams have also received attention, the general conclusion being that amalgams are mixtures of a solid and a liquid. An investigation[1] of the thermal expansion has shown that where the percentage of the metal other than mercury is very small the amalgam acts like a solution, but with greater percentage of the other metal (tin, lead, zinc) it is apparently a mixture of a liquid and a solid.

The study of the electrical properties of amalgams has been more thorough because of their use in the preparation of standard cells. Investigation of the electrical conductivity has, in general, gone to show that, for small percentages of foreign metals in the mercury, the effect is that of a solution; while for greater percentages, apparently a mixture of liquid and solid is present; thus confirming the results of the investigations of the thermal expansion and specific gravity. The study of the electro-motive force of amalgams has given more definite results. In the case of the alkali metals it has been demonstrated that more than one inter-metallic compound is formed with mercury. Haber[2] concluded generally that the metals in amalgams either were in the atomic state or formed compounds of the type Hg_mM.

The microscopic examination of polished surfaces of amalgams has so far yielded but unsatisfactory results, due to the difficulties arising from the presence of the liquid phase. The study of the freezing-point curves has been more productive, but is not entirely concordant with the foregoing work. In the case of the tin-amalgams, Van Heteren[3] has found that either tin, or a solid solution of mercury in tin, freezes out from the liquid down to –34.5° C., at which point a transformation takes place, and the new form, "probably mixed crystals," freezes out to the solidification point of mercury. Roozeboom[4] has shown that, in the series Cd-Hg, above 77 per cent. of Cd mixed crystals separate out; below 67 per cent. of Cd other mixed crystals of the Hg type separate out; between these ranges the action is more complex. Cd is insoluble in solid mercury.

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[1] Cattaneo, *Atti della Reale Accademia delle scienze di Torino*, vol. xxv., pp. 342-59, 492 (1890).

[2] *Zeitschrift für physikalische Chemie*, vol. xli., p. 399 (1902).

[3] *Zeitschrift für anorganische Chemie*, series 2, vol. xlii., p. 129 (1904).

[4] *Proceedings Koninklijke Akademie van Wetenschappen, Amsterdam*, vol. iv., p. 1 (1901).

The most complete study of amalgams by means of their cooling-curves has been done by Pushin[5] who carefully traced the cooling-curves of the series, Hg-Bi; Hg-Cd; Hg-Zn; Hg-Pb and Hg-Sn. These curves showing no evidence of the separation of inter-metallic compounds, the author concluded that the series Hg-Zn and Hg-Bi are mechanical mixtures, and the series Hg-Cd, Hg-Sn and Hg-Pb are solid solutions. These results can scarcely be accepted without comment, but criticism does not find a proper place here. Mercury forms the eutectic for all the series, except Hg-Zn, where the eutectic occurs at about 2½ per cent. of Zn. Tamman[6] had already shown that for the series Hg-Zn and Hg-Bi the eutectic is very nearly pure mercury.

In conclusion, it may be said that with the alkali metals mercury forms a rather complicated series including several inter-metallic compounds.[7] With some of the other metals the amalgams consist of solid or liquid solutions or mixtures of both. Others are not yet completely understood.

III. Gold and Silver Amalgams.

1. *Native Amalgams.*—Naturally occurring amalgams of gold and silver have been found in some localities. Schneider[8] reports gold-amalgam occurring in small grains with the platinum of Colombia, and having approximately the composition Au_4Hg_5. An amalgam from the Mariposa region, California, analysed by Sonnenschein,[9] was nearly Au_3Hg_4 in composition. Silver-amalgam is more common, and numerous occurrences and analyses are cited in Dana's *System of Mineralogy.* The crystals of silver-amalgam are isometric, commonly dodecahedral, the analyses vary from Ag_2Hg_3 to nearly pure silver. Isometric crystals occurring in cavities filled with mercury, at

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[5] *Zurnal russkago physiko-chimiskago Obshestvo*, vol. xxxiv., p. 856 (1902). *Zeitschrift für anorganische Chemie*, xxvi., p. 201 (1904).

[6] *Zeitschrift für physikalische Chemie*, vol. iii., p. 441 (1889).

[7] Schuller, *Metallurgie*, vol. i., p. 433 (1904). Kurnakov, *Zurnal russkago physiko-chimiskago Obshestvo*, vol. xxxi., p. 927 (1899).

[8] *Journal für practische Chemie*, vol. xliii., p. 317 (1848).

[9] *Zeitschrift der Deutschen geologischen Gesellschaft*, vol. vi., p. 243 (1854).

Sala, Sweden, analysed by Sjogren,[10] had the composition Ag_2Hg_3. But in the case of these amalgams it is only where there is excess of mercury present that we can be certain that no mercury has been lost by alteration. It is extremely difficult to free the amalgam from this excess of mercury and the analyses do not seem to justify a more definite statement than that the composition of natural amalgams is somewhere near AuHg and AgHg.

2. *Artificial Amalgams.*—Joule[11] in 1850 described the preparation of a silver amalgam by the action of silver-nitrate on mercury. He used a pressure of 72 tons (per square inch?) to press out the excess of mercury, and in this way produced a hard mass of shining crystals to which he gave the formula AgHg.

Henry[12] treated finely-divided gold with mercury, removed the excess of the latter by pressing through chamois leather, and treated the residue with hot nitric acid, thus obtaining yellow shining crystals to which he assigned the formula Au_8Hg.

DeSousa[13] attempted to obtain amalgams free from excess of mercury, by holding them at a high temperature and ordinary pressure until there was no further loss of weight. The temperatures used were those of boiling mercury, sulphur and diphenylamine. At the temperature of boiling mercury, he obtained Au_9Hg and $Ag_{11}Hg$. In sulphur vapor Au_9Hg and $Ag_{13}Hg$ were produced, while with diphenylamine Au_8Hg and Ag_4Hg were found.

Merz and Weith[14] later repeated this work more carefully, conducting the heating in a stream of hydrogen or nitrogen. They found that the loss of mercury was apparently continuous, though very slow, in the later stages, and concluded that the amalgams are decomposed at the boiling-point of mercury and that the small amount of mercury retained is mechanically held.

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[10] *Geologiska Föreningens i Stockholm Förhandlinger*, vol. xxii., p. 187–190 (1900).

[11] *British Association Report*, 1850, p. 55.

[12] *Philosophical Magazine*, series 4, vol. ix., p. 468.

[13] *Berichte der Deutschen chemischen Gesellschaft*, vol. viii., p. 1616 and vol ix., p. 1050.

[14] *Berichte der Deutschen chemischen Gesellschaft*, vol. xiv., p. 1438.

Schnauss[15] and Dudley,[16] repeating the work in the same manner as De Sousa, obtained similar results.

Knaffl,[17] using HNO_3 of 1.35 sp. gr. at a temperature of 80° C., separated isometric crystals which he states to be nearly pure gold. Chester[18] found that, beginning with cold nitric acid of 1.2 sp. gr., gently heating, and finishing with hot acid of 1.4 sp. gr., elongated needles could be obtained which appeared to be hexagonal prisms terminated with pyramids and base. These contained about 6 per cent. of mercury. Both Knaffl and Chester were investigating the crystallization of gold, and paid little attention to the mercury content of the crystals. Wilm[19] by the use of nitric acid obtained needles and prisms which contained from 9.87 to 11.45 per cent. of mercury. Fedorow[20] states that the crystals left by the treatment of gold-amalgam with nitric acid are prismatic, belonging to the hex-octahedral class, being elongated in a direction perpendicular to the octahedron faces. Fremy[21] states that a white crystalline mass having the composition $AuHg_4$ can be separated from gold-amalgam. Many other statements in regard to the composition of gold-amalgams can be found scattered through technical journals and text books, but these are usually vague or are based on very slender evidence.

Kasantseff[22] studied the action of nitric acid on solid and liquid gold-amalgams, concluding that the resulting alloys were not homogeneous in character. He also investigated the solubility of gold in mercury, by filtering a liquid amalgam through capillary tubes, and determined a solubility of 0.011 per cent. of gold at 0° C., 0.126 per cent. at 20° C. and 0.65 per cent. at 100° C. Dudley[23] checked this work by allowing mercury containing 0.1 per cent. of gold to stand quietly for several months at 20° C. in a tall glass cylinder. The mercury decanted from the top at the end of this time contained 0.068 per cent. of gold, and after filtering through boxwood contained 0.06 per cent. of gold, indicating that the higher figures are due to the presence of fragments of gold or gold-amalgam so minute as to pass through the filtering device employed.

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[15] *Archiv der Pharmazie*, series 3, vol. vi., p. 411.

[16] *Proceedings American Association for the Advancement of Science*, vol. xxxviii., p. 145 (1889).

[17] *Dingler's Polytechnische Journal*, vol. clxviii., p. 282 (1863).

[18] *American Journal of Science*, series 3, vol. xvi., p. 29 (1878).

[19] *Zeitschrift für anorganische Chemie*, vol. iv., p. 325 (1893).

[20] *Verhandlung der russischen Kaiserlichen chemischen Gesellschaft*, vol. xxx., p. 455 (1893).

[21] *Encyclopedie e Chimique*, vol. iii., p. 99.

[22] *Bulletin de la Société Chemique*, series 2, vol. xxx., p. 20.

[23] *Proceedings of the American Association for the Advancement of Science*, vol. xxxviii., p. 160 (1889).

Berthelot[24] studied the heat of formation of various silver amalgams; the results are significant, but are not easily explained. Ogg[25] has investigated the chemical equilibrium between silver nitrate solution and mercury. He found that beyond a certain concentration of silver in the mercury a solid phase separates out. By the use of methods analgous to those generally adopted for hydrated salts the composition was determined to be Ag_3Hg_4. This agrees very closely with the naturally occurring silver amalgam.

3. *Research Work.*—The work of Pushin on the cooling-curves of amalgams resulted in the acquiring of definite data in regard to their constitution. The attempt was therefore made to apply this method of study to the gold-amalgams. A nickel-copper thermo-electric couple was prepared and calibrated for the purpose; nickel-copper being employed rather than platin-rhodium because of its much greater sensitiveness, especially for the ranges of temperature within which it was intended to be employed.

The mercury used was chemically pure, having been purified by redistillation and treatment with acid. The gold employed was inquarted and parted with nitric acid, then dissolved in aqua regia, and precipitated by warming with ethyl alcohol, yielding a bright crystalline powder which was readily taken up by the mercury.

Since mercury forms the eutectic of the gold-mercury series it is evident that for mixtures high in mercury the freezing-point curve coincides with the solubility curve of gold in mercury. The solubility of gold in mercury being known from the researches of Kasantseff and Dudley, it was easy to prepare an alloy of such composition that on cooling from the molten state the solid phase should begin to separate out near 100° C. This was placed in a small hard glass tube surrounded by a mixture of magnesia and asbestos, the whole being enclosed in a crucible and carefully covered to exclude drafts. It was raised to a temperature of 150° C. and slowly cooled. The cooling-curve was perfectly smooth, without any breaks whatever. The experiment was repeated several times with always the same result. Mixtures containing more gold were then employed and the initial heating was carried to higher temperatures, finally using a mixture in which it was evident that there was a solid phase still present near the boiling point of mercury. So much mercury is lost by volatilization at these high temperatures that any results which might have been obtained would have been untrustworthy.

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[24] *Comptes rendus*, vol. cxxxii., p. 241 (1901).

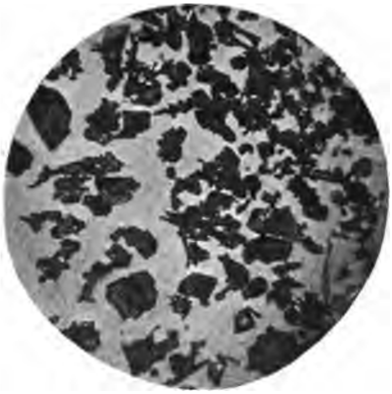
[25] *Zeitschrift für physikalische Chemie*, vol. xxvii., p. 285 (1898).

No breaks in the cooling-curve could be detected, and it became evident that this method of research was unproductive of results. Probably this was because the lag of the solid phase was not marked enough to produce a distinct jog in the curve. It was not possible to work with mixtures high in gold, for the mercury is lost by volatilization below their fusing-points at ordinary pressure, and the facilities were not at hand for working under high pressures. The study of cooling-curves, therefore, had to be abandoned, without having secured any definite results.

But this work had shown that a solid phase is present at ordinary temperatures with alloys low in gold. The constitution of this solid phase was the next subject of investigation. It was inferred that if an alloy was prepared in which the gold was entirely in solution in the mercury, and this alloy subjected to the action of a solvent which would dissolve the mercury, but not attack the solid phase, then we would get practically the effect of the freezing-out of the solid phase by the removal of the mercury with which it was in equilibrium, finally leaving only the solid phase present.

Nitric acid was judged to be the most likely solvent to yield good results. An excess of the finely-divided gold was added to mercury, and the mixture held at 100° C. The resulting liquid was filtered off and treated with nitric acid of different strengths, both at 100° C. and at ordinary temperature. The results were very variable. Acid of 1.42 sp. gr. at 100° C. gave a brownish powder, of indistinct structure, which was nearly pure gold, becoming bright on ignition. With acid of less and less strength the solid contained more mercury, and with 1.1 acid the residue contained 13.62 atomic per cent. of mercury (*i. e.*, 13.62 atoms of mercury in 100 atoms of the alloy). Numerous determinations on this residue showed it to be fairly uniform in composition throughout.

The residues were examined under the microscope by reflected light, using magnifications of 40 and 60 diameters. The powders from the stronger acid were indistinctly crystalline, apparently isometric where the form could be distinguished. The residue from the 1.1 acid was made up of distinct isometric crystals of a golden color, the octahedron and cubo-octahedron being the forms observed. Scattered throughout these were a few long needles of a bright brassy yellow; their form could not be determined beyond that they were apparently elongated prismatic crystals. Good photographs of this crystal mixture could not be obtained because of the nature of the material, but Fig. 1 shows its general isometric character.

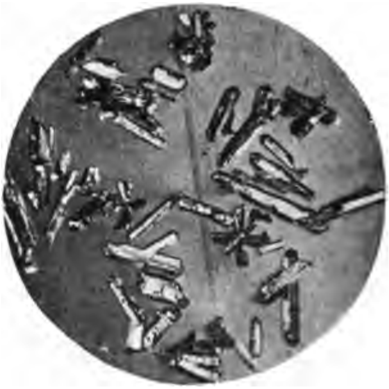


Magnified 60 Diameters.

FIG. 1.—GOLD-MERCURY SERIES. ISOMETRIC CRYSTALS, SOLID SOLUTION.

With the use of nitric acid of 1.05 sp. gr. different results were obtained. The entire residue consisted of the brassy yellow crystals, and these were now so well developed that they could be distinctly seen to be hexagonal prisms terminated with pyramids and the basal pinacoid. Their surfaces were bright and they had evidently not been attacked by the acid. On analysis they proved to contain 17.44 atomic per cent. of mercury. They are shown in Fig. 2.

Subsequently to reaching these results it was discovered that A. H. Chester[26] had described hexagonal crystals of gold-amalgam, stating that they contained about 6 per cent. of mercury. Fortunately Chester's original material was still available for study, and upon examining it the pitted and corroded surface of the crystals was ample evidence that mercury must have been lost by the use of too strong acid. Chester used 1.2 acid at 18° C. at the start, finally finishing with strong hot acid, hence the composition obtained.



Magnified 40 Diameters.

FIG. 2.—GOLD-MERCURY SERIES. HEXAGONAL CRYSTALS, INTER-METALLIC COMPOUND OR SOLID SOLUTION.

An attempt was made to study polished surfaces of the gold-mercury alloys. The surfaces were obtained by casting on glass and mica. In every case the excess of mercury present coated the crystals, giving only indistinct, rounded outlines from which nothing could be inferred.

Having thus learned the degree to which mercury is soluble in gold, the solubility of gold in mercury was next investigated. The differing results of Kasantseff and Dudley have already been cited. The methods used in checking these results were two in number: adding an excess of gold, heating to a higher temperature and filtering at the temperature desired; and suspending a thin sheet of gold below the surface of the mercury, holding the two for several days at the temperature at which it was desired to obtain the solubility and then analysing the mercury. In the former method fine cambric and close-grained chamois were used for the filters. It was found that the apparent solubility varied with the closeness of the filter, the pressure used in filtering, and also the degree to which the liquid had previously been heated, thus sustaining the contention of Dudley that the apparent solubility is due in part to the presence of minute solid particles which have passed through the filter. The results, though irregular, indicated that the solubility is at least not higher than the figures given by Dudley, namely, 0.06 per cent. at 20° C. This conclusion was confirmed by the second method, which also gave a solubility of 0.25 per per cent. at 100° C. The first method gave, for the solubility at 100°, 0.35 per cent. In determining the solubility by diffusion, the liquid was held a few days at 100° C., but the diffusion may perhaps not have completed itself, and the true solubility may be the mean of the two figures.

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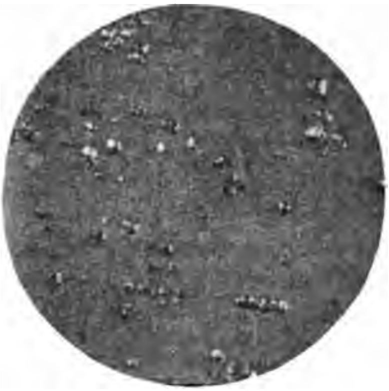
[26] *American Journal of Science*, series 3, vol. xvi., p. 29 (1878).

The solubility of gold in mercury is very low indeed. Judging from the direction of the curve it is zero at the freezing-point of mercury, so that pure mercury is the eutectic of the gold-mercury series.

The results, though not entirely satisfactory, seem to justify the conclusion that in the gold-mercury series where the content of gold is high, a solid solution of mercury in gold which is isomorphous with gold separates out. This solution may contain as much as 13 atomic per cent. of mercury. In the lower ranges of the series, what seems to be an inter-metallic compound (holding gold or mercury in solid solution) containing 17.44 atomic per cent. of mercury separates out; this crystallizes in the hexagonal system. From results on other amalgams, there remains a question as to whether this is really an intermetallic compound rather than a solid solution differing from the first. This question, and others not completely answered in the foregoing work, can be decided, but only after a large amount of very careful work. Their importance as bearing on the question actually under investigation did not appear to be great enough to justify undertaking such work at this time. Finally, gold is practically insoluble in solid mercury, and the solubility in liquid mercury for ordinary ranges of temperature is very slight indeed.

The investigation of the silver-mercury series presents all the difficulties of the gold-mercury series, with the added one, that no solvent could be found which would attack mercury without attacking the solid phase. The only results worth mentioning were obtained by placing a solution of silver in mercury on silver plates and allowing the silver plate to absorb the excess of mercury. In this way the crystals were obtained that are shown in Figs. 3 and 4. These show the presence of two series of crystals, one apparently isometric and the other prismatic, with some modifying faces. From this evidence it may be inferred that silver is similar to gold in the forms which separate out from its series with mercury. The crystals were too small to analyze.



Magnified 40 Diameters.

FIG. 3.—SILVER-MERCURY SERIES. ISOMETRIC CRYSTALS.

In this connection it must be remembered that Ogg[27] has shown that silver forms the inter-metallic compound, Ag_3Hg_4, with mercury.

IV. MECHANICS OF THE AMALGAMATION PROCESS.

By the foregoing considerations the belief is confirmed that amalgamation is a physical rather than a chemical process. The solubility of gold in mercury is almost negligible, and the diffusion of the mercury into the gold, forming a solid solution or inter-metallic compound, is a rather slow process, unless the gold is very finely divided, whereas the "catching" of the gold by the mercury is almost instantaneous. It is from a study of the physical features of the process that information is to be derived regarding the proper conduct of the operation. Yet it must not be forgotten that although amalgamation is, with respect to any given particle of gold, an almost instantaneous process, with respect to the total mass of ore it is a continuous process, and any change, however slow, must in time produce either beneficial or detrimental effects. All the forces which operate must therefore be considered, and their relative effects determined.

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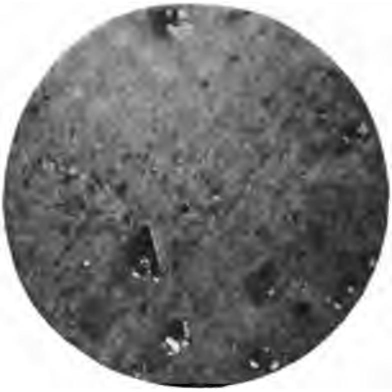
[27] *Zeitschrift für physikalische Chemie*, vol. xxvii., p. 285 (1898).



Magnified 40 Diameters.

FIG. 4.—SILVER-MERCURY SERIES. PRISMATIC CRYSTALS.

With the exception of the tellurides, gold occurs in its ores as metallic or free gold, though frequently alloyed with greater or less amounts of silver, and, less frequently, with some other metals. Whether the tellurides of gold and silver are alloys or compounds is not a proper question for discussion here. The ores of gold are usually divided into two classes, "free milling" and "refractory" ores.

The closest practicable definition of these is that, in a "free-milling" ore, the gold occurs in such a form that it is readily and fairly completely recovered by crushing and amalgamation, while in refractory ores this is not the case. That the refractoriness of an ore may arise from one or more of a variety of conditions will be easily seen after outlining the physical features of the amalgamation of a "free-milling" ore.

The purpose of the crushing operations, usually performed in a stamp mill with water, is to free the gold from the adhering gangue. The action of a stamp has been aptly likened to that of a hammer cracking a nut and liberating the enclosed kernel. If the stamp has done its work properly the pulp, as it passes through the battery-screens, consists of particles of gangue and particles of free gold. This pulp is caused to pass over copper plates coated with mercury in a thin film. No mineral matter other than metal is susceptible of being wetted by the mercury, and, in addition, all the ore-material other than the metal is much less in specific gravity than the mercury; hence it flows over the mercury surface without being affected by it. The gold, on the other hand, on coming in contact with the mercury is immediately wetted by it, just as any ordinary solid is wetted by water; the action of the two liquids, water and mercury, being identical from a physical standpoint, their apparent differences being due to the differences in their physical constants. This action is assisted by the fact that gold has a greater specific gravity than mercury, and therefore readily sinks beneath its surface; but this feature is not so important as an earlier writer[28] has claimed, for silver and the other lighter metals are readily amalgamated when their surfaces are in proper condition to be wetted by the mercury.

The gold particle, therefore, sinks beneath the surface of the mercury film which coats the plates, or, in mill-parlance, it is "caught." If the diameter of the particle is less than the thickness of the mercury film, it produces no disturbing effect on it. If, however, its diameter be greater than this, as will always be the case with coarse gold, the condition of affairs produced is as shown in Fig. 5.

The mercury rises over the grain of gold. But, as is well known, every liquid has a tendency, due to surface tension, to provide itself with a horizontal upper bounding surface. In the attempt to do this in that part of the surface which is elevated by the gold grain lying beneath, the pull of the surface tension is resolved into components which press down the gold grain against the plate with a force which is considerable, compared with the dimensions and weights involved. This force begins to be exerted the instant the grain of gold is wetted by the mercury, and continues to operate until the grain is drawn beneath the surface; it constitutes the so-called "attraction" which mercury possesses for gold. Its exact amount may be computed, knowing the size and shape of the grain, the thickness of the film and the temperature. Under the influence of this force the grains of gold are caused to adhere to each other and to the plate with great tenacity, especially if it is assisted by the splashing or dropping of the pulp.

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[28] Church, *Scientific American*, Oct. 7, 1871. *Mineral Resources West of the Rocky Mountains* (Raymond), 1872, p. 422.

A third factor, which is of great importance in causing amalgam to become hard, is a slow molecular flow, or some action of similar character. An amalgam of finely-divided gold and silver, made up to the consistency of a soft paste, will, after standing several days, become quite hard and rigid, but after kneading with the fingers assumes its original consistency. On standing again, it becomes as hard as before, and this operation may be repeated indefinitely. The hardening is much accelerated at higher temperatures, and, while it may be in part due to agglomeration caused by slight changes in the amount of mercury in solution in the silver or gold, resulting from the daily variations of temperature, yet chiefly it seems to be due to a movement of the particles of the metal, causing cohesion. Under the influence of these three factors the amalgam accumulated on a plate sometimes becomes quite hard, requiring considerable force to remove it.

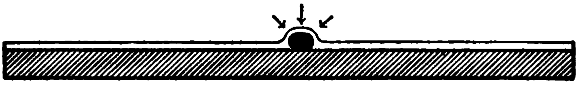

FIG. 5.—EFFECT OF CONTACT OF A GRAIN OF GOLD WITH A THIN LAYER OF MERCURY.

It follows, accordingly, that any condition which tends to make the gold particles less easily wetted by the mercury has an important detrimental influence on amalgamation. These conditions are many and varied. The influence of grease of any sort is so well known that it needs only to be mentioned. If the gold has not been liberated by the crushing, it cannot, of course, be caught, and if it has been only partially liberated the tendency of the mercury to hold the gold particle may be overbalanced by the tendency of the current to sweep along the adhering particle of gangue. Gold alloyed or combined with other substances is frequently rendered by them incapable of being wetted by the mercury. This is the case with the tellurides. Some writers have asserted that gold occurs in certain ores as a sulphide, but the evidence adduced to prove such a contention is inconclusive. Gold alloyed with bismuth is similarly affected, and there may, perhaps, be other cases. Much more common, especially in ores which have been subject to alteration, are adherent coatings of minerals which are not wetted by the mercury. These are commonly oxides, but may be sulphides or other gangue minerals. One case has been noted where the gold particles were coated with a film of chalcedonic silica. Such coatings are often difficult to remove, and it may be necessary to resort to some process other than amalgamation. A more lengthy discussion of them and their effects can be found in the references given below.[29]

Another cause suggested for the refusal of mercury to wet gold at times is that the latter may be in a strained state. Egleston[30] reported that gold, after hammering or rolling until it was brittle, would not amalgamate, though it had been cleaned with acid. T. K. Rose[31] reports that he was not able to confirm these observations. On rolling down pure gold until it was extremely brittle, I found that it would not amalgamate, even after cleaning with acid. But, on the surface being carefully cleaned with No. 0000 French emery-paper, it readily amalgamated, demonstrating that the refusal of the mercury to wet its surface was due to the dust and dirt which had been pressed into it, and not to the strained condition of the metal.

Very fine gold may be carried along so rapidly by the current that it does not come into contact with the mercury. To prevent this as far as possible, the outside plates are given such a grade that as little water may be used as is consistent with securing free movement of the pulp. Even if brought into contact with the mercury, it may refuse to become wetted by it, because the mercury is not able to displace the air or liquid film already adhering to such fine particles. The application of similar action in the case of some sulphides in the various flotation processes is already known. The refusal of mercury to wet very fine gold has been noted by many writers, and Louis[32] has ascribed it to the existence of an allotropic modification of gold which is not wetted by mercury. This may be the case, but very finely-divided silver also refuses to be wetted by mercury, and it is perhaps better to leave the matter as an open question until further proof can be adduced.

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[29] Egleston, *Metallurgy of Gold, Silver and Mercury*, pp. 584–95. McDermott and Duffield, *Losses in Gold Milling*.

[30] *Trans.*, ix., p. 648 (1881).

[31] Rose, *Metallurgy of Gold*, p. 149.

It is usually the case that mercury is fed into the stamp battery in order that, during the agitation of crushing, the gold may be brought into contact with the mercury, each grain being thereby thoroughly wetted. By the violent agitation during crushing, the mercury is subdivided into very small globules, thereby greatly increasing the chances that every gold particle will be brought into contact with the mercury and receive an adherent coating, which practically insures its being "caught" by the plates. This is for a triple reason: the weight of the particle is greatly increased, it is made more nearly spherical and correspondingly less likely to be carried off by the current of water, and, finally, the mercury film of the plates more readily "catches" a wetted particle than a dry one. To express the last statement in another way, mercury has less surface tension against mercury than it has against gold. This subdivision of mercury into fine globules is one of the most important functions of the stamp-mill, and many authorities ascribe the excellence of stamp-milling as a process for the treatment of gold-ores principally to this feature of the operation.

But disadvantages are also introduced by this practice. The most important of these are the losses brought about by the "sickening" and "flouring" of the mercury. This arises chiefly from one or all of three causes. The first is purely mechanical. By the agitation in the battery the mercury is broken up into such small drops that the surface tension of each is enormous, compared to its weight. This great surface tension[33] then keeps the globules perfectly spherical, and when they come into contact it is only at a point rather than along a line or upon a surface; the tendency of two globules to coalesce when they come into contact, or to sink beneath the mercury surface, is therefore very slight, and they are carried away with the pulp and lost. The tendency to settle is also very slight, just as a pebble, which falls to the earth rapidly, will, after being ground to dust, float in the air indefinitely. The second cause is also mechanical, and arises from the presence of certain minerals which yield very fine slimes that adhere to the mercury surface, though not wetted by it. When covered with this fine coating the globules can scarcely be made to coalesce with each other or with the mercury or the plates, and their loss is almost unavoidable, though the use of mercury traps is of considerable assistance.

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[32] *Trans.*, xx., 182, and xxiv., 705.

[33] The surface tension of mercury against water at 20° C. is 418 dynes per linear centimeter. Quincke, *Weidemann's Annalen*, 1886, p. 219.

An entirely similar action with water can be seen by sprinkling drops of water on a surface previously coated with lycopodium powder. Each drop becomes coated with the powder, taking on a spherical shape, if small, and moving about with the "quickness" of mercury. The drops can scarcely be made to coalesce, even if brought together with considerable force. The oxides of manganese and certain sulph-antimonides and sulph-arsenides are the worst offenders in this regard in amalgamation. It is reported that, in certain instances, the addition of various chemicals has been beneficial in preventing this action, but the data are not conclusive.

The third cause is chemical, and is a double source of loss. Soluble salts in the ore react with the mercury, causing it to be lost in solution, and precipitating other elements into it, causing it to become "sick." "Sickness" is of two kinds. Any other metal alloyed with the mercury makes it much more viscous and less "quick." A practical use is made of this fact in astronomical and physical work, where a mercury surface is used as a reflector. Mercury alone is too sensitive, vibrating constantly, but the addition of a small amount of tin causes it to stiffen enough to be perfectly satisfactory. In the case in hand this action is undesirable, for it causes the mercury to subdivide so readily that "flouring" takes place to an injurious degree. It is also undesirable for two other reasons: the fine slimes previously mentioned adhere much more readily to the surface of "sick" mercury, and the metals in the mercury frequently reoxidize, forming a coating which almost prohibits the coalescing of the drops, or their being caught on the plates.

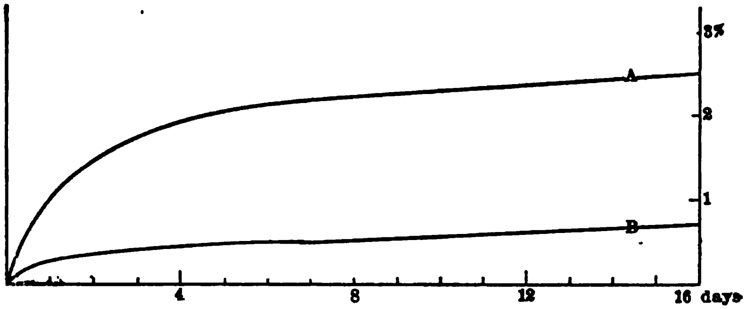
So far we have been concerned with actions that are comparatively rapid. But there are also others of a slower rate, and these now remain to be considered.

The first is the absorption of the mercury by the other metals taking part in the process. It has already been pointed out that mercury is soluble in gold up to about 17.5 per cent. The rapidity of its absorption depends directly on the surface exposed by the gold, and account is taken of this fact in the usual statement of mill men that more mercury is required to amalgamate fine gold than coarse. A large part of the mercury remaining in an amalgam after squeezing is held in solution in the gold, the remainder covering the particles in a film which assists in cementing the mass together.

1. *Absorption by the Plates.*—Important also is the absorption of the mercury by the plates. The investigation divides itself into two parts: the relative absorption of copper plates at different temperatures, and the relative absorption of different plates at ordinary temperature. For the former, sections of engravers' plate were used. They had each an area of 4.15 sq. in. and a thickness of 0.067 in., weighing approximately 40 grams. They were thoroughly amalgamated (using cyanide solution and sand) and kept submerged in mercury, the one at 100° C. (boiling-water) and the other at 0° C. (melting-ice) for three weeks, the rate of absorption being determined by removing the plates at intervals, freeing from the excess of mercury by rubbing and then weighing. It was not, of course, possible to free the plates entirely from adhering mercury, but by the use of care in the rubbing it was found possible to obtain fairly concordant results.

The curves A and B of Fig. 6 show that, as might have been expected, the rate of absorption is much faster at the higher temperatures, and the total amount absorbed is greater. Evidently from the direction of the curve the absorption is not complete, even at the end of three weeks. In the case of the plate held at 100° C. another factor enters in. Little gritty crystals are formed on the plate which are strongly adherent, but some few are removed by the rubbing. The plate, which was kept at 0° C., showed no indication of this, but in one instance a plate held at 20° C. did, to some extent. Apparently, then, the final limit of the absorption of mercury by copper plates is the formation of a solid solution or inter-metallic compound of a definite crystalline form.

The rate of absorption and total solubility depend on the temperature. One effect of the rise in temperature of plates that are in equilibrium can immediately be seen from an inspection of the diagram. On raising the temperature, more mercury will go into solution in the copper and also in the gold, and if more mercury is not fed to the battery, the plates will become dry and hard. The absorption is so slow that it will require several weeks to complete itself at the raised temperature, and, during that time, progressively varying conditions will have to be dealt with. Hence the importance of keeping the temperature constant to avoid changes in the hardness of the amalgam.

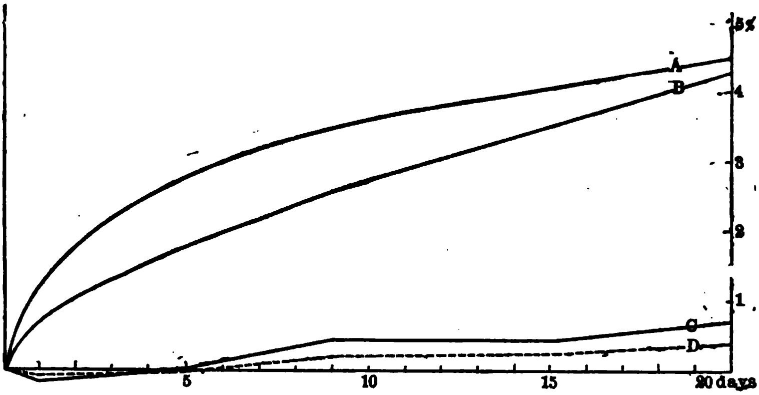


A. Plain copper, absorption at 100° C. B. Plain copper, absorption at 0° C.

FIG. 6.—ABSORPTION OF MERCURY BY COPPER PLATE.

To obtain the relative absorption-rates of plain and silvered copper plates, two similar plates were cut from electrolytic sheet-copper, and ground down to plane surfaces and rounded edges. Each had an area of 4.85 sq. in. and a thickness of 0.06 in. One was then silver-plated to a thickness of 0.005 in. Both plates were then amalgamated, kept submerged in mercury at 20° C., and the rate of absorption determined as before. The silver plate retains a little more mercury as an adherent coat because of the greater specific gravity of the silver. The silver film somewhat restrains the diffusion of the mercury through it at first, but the ultimate effect differs little in the two cases.

The chief difficulty encountered in the use of plain copper plates is due to the fact that the small amount of copper which goes into solution in the mercury is very easily attacked by oxidizing agents and the salts which go into solution during the crushing of the ore, thus forming a tarnished film of copper salts on the surface of the mercury. Even the oxygen in solution in ordinary water produces this effect to an undesirable degree, but in the case of some ores containing certain soluble salts the action frequently is so strong that no gold can be caught, as very little clean mercury surface is exposed. What these salts are is not known except in a few cases. The data are not accurate enough to base generalizations upon. This difficulty is obviated by silver-plating the copper plates. The silver is soluble in the mercury to a very much less degree than is copper, and is also much less affected by the salts in question, probably not being at all acted on by the oxygen. The effect of the silver-plating on the absorption of the mercury by the copper is to restrain it at first, since the mercury has to diffuse through the silver. Eventually, however, the total amount absorbed is approximately the same, as is shown by the two curves, A and B, of Fig. 7.



A. Plain copper. B. Silvered copper. C. Thin Muntz metal. D. Thick Muntz metal.

FIG. 7.—ABSORPTION OF MERCURY BY PLATES OF DIFFERENT METALS.

The effect of the physical condition of the plates is also of great importance. It will have been noticed by comparing Figs. 6 and 7 that the rolled engraver's plate at 100° C. absorbed more slowly than the electrolytic sheet-copper at 20° C. This was due to the difference in their structure, since the work was carefully repeated in each case.

2. *Use of Muntz Metal Plates.*—Muntz metal for battery-plates has been employed in Australia, and its use has been warmly commended,[34] but apparently has not spread much in this country or elsewhere. The advantages claimed for it are that it is cheaper, lasts longer, requires less attention, is easier to remove the amalgam from, and does not discolor. The solubility of mercury in Muntz metals was investigated, and plates for this purpose were kindly prepared by Mr. Frederick Maeulen (to whom my grateful acknowledgements are made). The metal had the composition, zinc 38.1 and copper 61.9 per cent. Plate C had an area of 5.11 sq. in. with a thickness of 0.0256 in.; while plate D had an area of 4.92 sq. in. and a thickness of 0.014 in. The plates were annealed and kept submerged in an excess of mercury. The negative reading at the end of the 24 h. is probably due to the mercury dissolving out zinc faster than it was itself absorbed. The solubility ot mercury in Muntz metal is seen to be very low. The divergence of the curves emphasises the fact that the rate of absorption is proportional to the surface exposed, plate C having a much larger surface in proportion to its weight. The percentages are by weight compared to the original weight of the plate. The curves also indicate that the absorption is very slow, and is not completed within the time during which observations were taken.

Hockin and Taylor have shown[35] that mercury dissolves the zinc out of brass. No copper could be detected in solution in the mercury at the end of the period. From these facts the reasons for the excellence of Muntz metal for plates become reasonably clear. Since no copper goes into solution in the mercury, no trouble is experienced from oxidizing agencies, and the necessity for silver-plating is removed in most cases. However, in working waste heaps[36] (which probably contained copper sulphate) the Muntz metal plates coated badly; the small amount of zinc in the mercury producing even more undesirable results than would copper in such cases.

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[34] Rickard, *Stamp Milling of Gold Ores*, pp. 179–182.

[35] *Journal of the Society of Telegraph Engineers*, vol. viii., p. 282.

[36] Rickard, *Stamp Milling of Gold Ores*, p. 182.

The Muntz metal consists almost entirely of an inter-metallic compound of copper and zinc. Mercury is very slightly soluble in this compound (perhaps not at all, for the slow gain in weight may be due to the slow replacement of one metal of the compound by the mercury). Gold is presumably also very slightly soluble in it, and this explains the slight adherence of the amalgam to these plates, for, beyond question, the strong adherence of amalgam to copper or silver plates is due to the slow diffusion of the gold into the metal. Roberts-Austen[37] has shown that gold diffuses into lead when brought into contact with it; and it is well known that alloys can be produced by pressing together finely divided metals that are capable of forming an alloy. This slight adherence is both an advantage and a defect, for it allows a closer cleaning up of the amalgam, and also makes it more frequently necessary. The thickness of the mercury film on the plates must also be important. The thickness of the film which a plate of a given inclination will hold depends on the specific gravity of the holding surface. Hence, silvered plates will hold a thicker film, and Muntz metal a thinner. Plates well coated with gold amalgam hold the thickest film possible. Hence, excessive scraping of plates is to be avoided, as the gain in daily yield of amalgam is more than counterbalanced by the loss of "catching" power.

Since the Muntz metal is an inter-metallic compound of zinc and copper, there could be no possibility of any galvanic action between the zinc and copper to affect the process. Muntz metal plates present many desirable features, but apparently the demand has not been great enough to lead to their manufacture.

V. INVESTIGATION OF DIRECT CHANGES DUE TO TEMPERATURE.

Whether variations of the temperature at which the process is conducted has any direct specific effect on amalgamation, has been the subject of much discussion. It will be impossible to refer here to all the statements made regarding this, but a few of the more significant must be mentioned. J. A. Grier[38] states that when two batteries were run side by side on the same ore, the one at 50° F. and the other at from 60° to 70° F., considerably more gold was caught by the battery at the lower temperature. J. A. Church[39] cites a case where water from old mine-workings was used that had a temperature of 135° F. at the battery; the plates coated badly and the recovery was very poor. T. A. Rickard[40] says that at Black Hawk, Colo., the recovery is better in winter than in summer, and objects to the practice at the Brittania United, Ballarat, of warming the battery-water. Louis Janin[41] says that no advantage is gained by heating the battery-water. At the Golden Star mill, Supt. Reed[42] changed a battery from 56° F. to 70° F. In 24 hr. the amalgam had nearly all scoured off. This was a silver plate; the copper was not affected. It is not stated whether all other conditions were kept constant, and it is hardly safe to comment on such an experiment unless all the conditions are known. J. A. Sanborn[43] says that the objection to an increase in temperature is that the plates were prepared for a lower temperature, but that the adjustment may be made for any reasonable temperature. He also says that the chief objection to hot battery-water is the resultant increased solubility of deleterious salts. J. H. Thierman[44] suggests that the heated water causes any grease which may be present to more readily form a film over the gold and mercury. A. von Dessauer[45] found that the plate-amalgam contained from 20 to 35 per cent. of gold in the summer time, but only from 7 to 10 per cent. in winter. Besides these factors, R. H. Richards[46] mentions two others, the attraction of mercury for gold and the cohesive power of the mercury. It should be noticed, however, that the only attraction mercury has for gold is the surface-tension pull, previously mentioned; and that the facilitation of the coalescence of globules of mercury by a rise of temperature is not due to an increase of cohesive power, but to a decrease of their surface tension.

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[37] *Royal Society Proceedings*, vol. lxvii., p. 101 (1900).

[38] *Engineering and Mining Journal*, lxv., p. 126.

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[39] *Engineering and Mining Journal*, lxv., p. 158.

[40] *Stamp Milling of Gold Ores*, pp. 125–6.

[41] *Mineral Industry*, iii., pp. 328 and 343.

[42] *Engineering and Mining Journal*, lxv., p. 126.

[43] *Engineering and Mining Journal*, lxv., p. 397.

[44] *Engineering and Mining Journal*, lxv., p. 247.

[45] *Engineering and Mining Journal*, lxv., p. 760.

[46] *Ore Dressing*, p. 766.

The points in regard to the effect of temperature on the solubility of deleterious salts and resultant chemical reactions, their influence on "flouring," and the influence of rise of temperature on the surface tension and viscosity of the mercury, have already been treated as fully as seems necessary.

To determine whether other physical constants are appreciably affected by temperature changes, two lines of investigation were followed. The purpose of the first was to learn whether the plasticity of the mixture of liquid and solid, ordinarily known as "amalgam," varied to any sensible degree with ordinary ranges of temperature change.

For this purpose an apparatus was designed and constructed, in which a pasty mass of amalgam was held in a cup that was rotated by a small electric motor. The cup was provided with sharp points on the inside, so that the amalgam was obliged to rotate with it. Submerged in the mass of amalgam was a stirrer, turning in a ball bearing. The torsional pull on the stirrer, when the mass was rotated, was measured by a delicate helical spring. The whole apparatus was placed in a constant temperature chamber, and numerous observations made over the range from 18° to 100° C. (60° to 212° F.). Both silver- and gold-amalgams of the consistency of thick cream were used; it was necessary to employ very finely divided metal in preparing the amalgam in order to make it homogeneous. It was found that, as result of the increase of temperature, two conflicting changes tended to take place:—the amalgam tended to become harder from the increased absorption of the mercury by the gold, and softer from the decreased viscosity of the liquid mercury cementing the solid particles. The total change was very slight, and of the same order as the errors of observation due to the settling of the solid particles and the slight imperfections of the apparatus. A more detailed statement of the results, and a sketch of the apparatus, are therefore omitted. The investigation showed that the changes in plasticity induced by ordinary variations in temperature are negligible.

The purpose of the second investigation was to learn whether the adhesion of gold to mercury is sensibly affected by changes of temperature. To this end the inclination at which spheres of gold, silver and platinum, one-half an inch in diameter, will roll down an amalgamated copper-plate were observed. Two sets of angles were measured: that at which the spheres would start to roll from a state of rest (column A, Table I.), and the angle at which they would continue to roll after being started by a touch from a camel's hair brush (column B, Table I.). The inclination was measured for the dry plate at ordinary temperature (20° C.), the amalgamated plate at the same temperature, and the amalgamated plate at 100° C. The gold and platinum spheres were perfect to within 0.001 in.; the silver sphere was not so perfect, and gave more irregular results. The angles recorded in Table I. are the average of several observations. The plate was somewhat roughened by the action of the mercury at the higher temperature; this is especially noticeable in the angles at which the balls would start themselves. The gold and silver balls were previouly amalgamated for the determinations with the amalgamated plate, but the platinum ball, of course, was not. It is seen at once from an inspection of the results that the effect of variations of temperature on the adhesion of gold to mercury is also negligible.

TABLE I.—*Results of Adhesion Tests of Gold, Silver and Platinum Balls.*

	Platinum.		Gold.		Silver.	
	A.	B.	A.	B.	A.	B.
Dry plates, 20°............	1° 28′	0° 28′	1° 09′	0° 32′	2° 17′	0° 48′
Wet plates, 20°............	1° 45′	0° 28′	1° 48′	1° 15′	3° 07′	1° 57′
Wet plates, 100°..........	1° 43′	0° 54′	2° 03′	1° 30′	....	1° 30′

These facts are so completely in accord with the data obtained by the metallurgical and chemical investigations, that there seems no escape from the conclusion that amalgamation of gold-ores is mainly, and above all, a simple mechanical process. Such chemical forces as enter into it are only slight, and are mainly detrimental, as previously outlined. The chief physical factor is the surface-tension of the mercury, which causes the mercury to cling in an adherent film to the plates employed, to wet the gold grains, and to draw them beneath its surface. It also acts detrimentally, tending to prevent the globules of mercury from coalescing again when they are very finely divided. The solution of the gold and silver by the mercury is very slight indeed; that of the copper is more noteworthy, and gives opportunity for undesirable chemical actions. The absorption of the mercury by gold, silver and copper is large in amount. With gold, what is probably an inter-metallic compound is formed with excess of mercury at 100° (whether it can form at ordinary temperatures is not certainly known), but this is of no great importance in the ordinary application of the process. Some sort of molecular flow causes the grains of the amalgam to adhere strongly together on standing, and the slow diffusion of the gold into the plate causes the amalgam to adhere strongly to copper and silvered plates. According to Richards,[47] this diffusion does not extend to any great depth in the ordinary life of a plate.

The effect of changes in temperature on amalgamation is seen to be two-fold. The solubility of deleterious salts in the ore is, of course, increased by rise of temperature, their action is accelerated, and the solubility of copper in the mercury is increased, thus giving greater opportunity for these harmful reactions. But the most important effect is the disturbance of plate-equilibrium, resulting from changes of temperature. The thickness of the film of mercury which the plate will hold, and the absorption of mercury by the other metals concerned is changed, and the mill-man then has to deal with varying conditions, a state of affairs to be avoided, if possible. From the physical standpoint the temperature employed does not matter, so long as it is constant. From the chemical standpoint a low temperature is better in most cases. But it should be mentioned, in passing, that both the viscosity and surface-tension of mercury are lessened by rise of temperature, the differences for ordinary ranges of temperature being slight. Under certain circumstances, where chemical action is negligible, it seems that it might be advisable to conduct the process at elevated temperatures, for the wetting of the grains by the mercury is slightly facilitated by rise of temperature. The viscosity of mercury at 0° is 0.0169 dynes per sq. cm., and at 99° is 0.0128 dynes per sq. centimeter.[48]

In the operation of the stamp-milling process the character and gold content of the ore necessarily vary. If, in addition, the temperature, and with it all the foregoing factors, are allowed to vary, it becomes impossible to exert a proper control over the operation.

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[47] *Ore Dressing*, p. 765.

[48] Koch, *Poggendorf's Annalen*, vol. xiv., p. 1 (1881).

VI. SUMMARY.

1. Gold absorbs mercury, forming a solid solution which may contain as much as 13 atomic per cent. of mercury. Beyond this, an inter-metallic compound containing gold or mercury in solution (or a second solid solution) is formed, which contains 17.5 atomic per cent. of mercury. Ordinary amalgam, which is not in a state of equilibrium, consists of one or both of the foregoing, usually the former, mixed with an excess of mercury which coats the particles and causes them to cohere.

2. Amalgamation is a physical process, the chemical actions involved being chiefly inimical (excepting those purposely induced). The gold grains are wetted by the mercury and sink beneath the surface of the mercury film on the plates; this is facilitated by feeding mercury to the stamp, so that the grains may be thoroughly wetted before coming in contact with the plates. The disadvantages of this procedure have already been discussed. The surface-tension of the mercury draws the gold beneath the surface, and holds it against the plate. By diffusion into the metal of the plates the amalgam often becomes strongly adherent. Silver-plating is useful, because it prevents the solution of the copper in the mercury, and, therefore, the harmful chemical reactions that result therefrom. Muntz metal plates exhibit the same effect, and, in addition, diffusion of amalgam into them is very slight, so that it is readily removed. Silvered-plates will hold a thicker film of mercury than plain copper, and plates coated with gold amalgam a thicker film than either. This assists the "catching" of the gold.

3. Variations in temperature make themselves felt in slight changes of a number of factors rather than large changes in any one. According to the relative importance of these factors in each case the total effect may vary. The most important undesirable effects of raising the temperature are the increased solubility of harmful salts, and a corresponding increase of the precipitation of base metals into the mercury; this both hinders its proper action and leads to its loss. Rise of tempera-

ture also diminishes the surface-tension and viscosity of the mercury, which allows it to be more readily "floured." The force with which the gold is drawn beneath the mercury and held against the plate is also decreased. On the other hand, by an increase in temperature the wetting of the gold by the mercury and the "catching" of it by the plates is facilitated, as is the coalescing of the globules of mercury.

4. Increase of temperature causes increased absorption of mercury by the gold and by the plates. Changes in temperature cause changes in all the foregoing factors. The retaining of a constant temperature is therefore most favorable to successful working. A comparatively low temperature is better where the influence of soluble salts in the ore has to be considered (which is usually the case); but when this may be neglected, as high a temperature as can economically be maintained, without variation, is most favorable to successful amalgamation.

In conclusion, I desire to express my indebtedness to Prof. H. S. Munroe, who directed the investigation; and also to Dr. Wm. Campbell, who kindly took the micro-photographs, and aided in the metallurgical investigation.

SUBJECT TO REVISION.

[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

Proceedings of the Ninetieth Meeting, Bethlehem, Pa., February, 1906.

COMMITTEES.

General Local Committee.—John Fritz, *Chairman;* A. B. de Saulles, *Vice-Chairman;* R. M. Bird, *Treasurer;* Henry S. Drinker, *Secretary;* Robert H. Sayre, E. P. Wilbur, Charles M. Dodson, Abraham S. Schropp, E. M. McIlvain, Archibald Johnston, A. B. Fichter, G. G. Convers, W. A. Wilbur, Garrett B. Linderman, Frederick Conlin, George Pettinos, Albert Brodhead, Garrett L. Hoppes, M. B. Cutter, H. J. Seaman, C. A. Matcham, B. F. Fackenthal, Jr., A. L. J. Queneau, Geo. R. Elder, Eldridge Wilbur, William H. Chandler, Mansfield Merriman, Joseph F. Klein, William S. Franklin, William Esty, Joseph W. Richards, Howard Eckfeldt, John D. Irving.

Transportation Committee.—H. J. Seaman, C. A. Matcham, B. F. Fackenthal, Jr., A. B. Fichter, A. L. J. Queneau, Henry S. Drinker.

Hotel Committee.—Garrett B. Linderman, Charles M. Dodson, W. A. Wilbur, Garrett L. Hoppes, Albert Brodhead.

Steering Committee.—William S. Franklin, William Esty, John D. Irving, R. M. Bird, the members of the Tau Beta Pi Society of Lehigh University.

Committee on Meetings.—Henry S. Drinker, Joseph W. Richards, Howard Eckfeldt.

Entertainment Committee.—W. A. Wilbur, E. M. McIlvain, Archibald Johnston, A. B. de Saulles, G. G. Convers, A. L. J. Queneau, Garrett B. Linderman, Frederick Conlin, George Pettinos, Garrett L. Hoppes, Henry S. Drinker, William S. Franklin, Eldridge Wilbur, Robert M. Bird, *Secretary.*

The opening session was held at 8.30 p.m., Wednesday, February 21, 1906, in Gymnasium Hall of Lehigh University, which had been tastefully decorated with flags and bunting.

Dr. Henry S. Drinker, President of Lehigh University, and Secretary of the General Local Committee, called the meeting to order, and welcomed the Institute to the Bethlehems, where its first meeting, after its organization in May, 1871, at Wilkes-Barre, was held in August, 1871.*

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* Dr. Drinker was one of the 22 members—of whom only four survive—who organized the Institute at Wilkes-Barre; and, at the Bethlehem meeting which followed, he presented a paper on "The Works and Mines of the Lehigh Zinc Co." As President of Lehigh University, he succeeded, in 1905, the late Dr. Thomas M. Drown, another of the "original twenty-two." In his address of welcome, Dr. Drinker emphasized the intimate relations between the Institute and Lehigh University, established through the active membership of many Lehigh professors and graduates.

President James Gayley replied in a brief address, expressing the thanks of the Institute for the cordial welcome thus extended to it, and the pleasure with which so many of its members, especially of those who had participated in its early history, were now gathered once more in the Lehigh valley, which was the cradle of its infancy. In addition to what had been said already by President Drinker, Mr. Gayley recalled the names of many Lehigh valley men, who had been pioneers of the new industrial era, as well as potent factors in the success of the Institute. In this connection, he called attention to the significant fact that the members who joined the Institute during the first year of its existence came largely from the Lehigh valley, or were connected with the industries which it represented, and that of the names added during that period to the membership of the Institute, a surprisingly large number have become famous as scientific investigators and instructors, or as "captains of industry." In other words, the men who founded the Institute, or rallied to its support during the first year which followed, were men of first-class ability and promise, as attested by their achievements and present fame.

The Secretary announced the receipt of telegraphic notice of the death of Samuel Thomas, Catasauqua, Pa., an old and highly esteemed member of the Institute, and son of David Thomas, its first President.

The following paper was presented by the Secretary, in the absence of the author:

Biographical Notice of George H. Eldridge, by S. F. Emmons, Washington, D. C.

The following papers were presented in oral abstract by the author:

Biographical Notice of Edward Cooper, by R. W. Raymond, New York, N. Y.

Biographical Notice of Alexander B. Coxe, by R. W. Raymond, New York, N. Y.

Mr. Howard W. DuBois, of Philadelphia, Pa., gave an admirable and enjoyable exhibition of colored pictures of mountain scenery in British Columbia, Alaska, and the Yukon Territory, which was especially interesting to those who had attended the British Columbia Excursion of the last meeting of the Institute, and had traveled over much of the country described by Mr. DuBois.

After the close of the session, an informal reunion and reception, tendered by the officers of the University, completed the evening's enjoyment.

The second session was held at 10 a.m., February 22, in the Physical Lecture-Room of Lehigh University, President Gayley in the chair.

The following papers were presented by the authors, and discussed:

Notes on the Gayley Dry-Air Blast-Process, by Carl A. Meissner, New York, N. Y. (Discussed by Messrs. H. M. Howe, Joseph W. Richards, Frank Firmstone, R. W. Raymond and James Gayley.)

Piping in Steel Ingots, by N. Lilienberg, Philadelphia, Pa.

The Present Condition of the Metallurgy of Aluminum, by Joseph W. Richards, Lehigh University, South Bethlehem, Pa.

At the close of this session, luncheon was served by Lehigh University in the spacious gymnasium of that institution, and opportunity was given to inspect, under the competent guidance of the "Steering Committee" of Lehigh students, the laboratories, collections, lecture-rooms, etc., of the University.

The third session was held at the same place, at 2.30 p.m., February 22. The following paper was read by the Secretary, in the absence of the author:

A Novel Method of Mining Kaolin, by Albert R. Ledoux, New York, N. Y.

The following papers were presented by their authors, and discussed:

A Reconnaissance for the Platinum Metals in British Columbia (illustrated with lantern views), by Howard W. DuBois, Philadelphia, Pa.

The Secondary Enrichment of Copper-Iron Sulphides, by Thomas T. Read, New York, N. Y.

The following papers were presented in printed pamphlets:

The Use of High Percentages of Fine Ore in a Charcoal Blast-Furnace, by Harry R. Hall, Standish, N. Y.

An Old Specimen of American Spiegeleisen, by Frank Firmstone, Easton, Pa.

Bibliography of Coal-Washing, by S. S. Wyer, Columbus, O.

The Beard-Mackie Sight-Indicator for the Measurement of Marsh-Gas in Collieries, by M. H. Harrington, Philadelphia, Pa.

Fine Grinding of Ore by Tube-Mills and Cyaniding at El Oro, Mexico, by Gelasio Caetani, El Oro, Mex.

Crushing-Tests of the Diamonds Used in Drilling, by Alexander N. Mitinski, St. Petersburg, Russia.

The Mining, Preparation and Smelting of Virginia Zinc-Ores, by Thomas L. Watson, Blacksburg, Va.

The Ancient Copper-Mines of Lake Superior, by Alvinus Brown Wood, Detroit, Mich.

The Relative Merits of Large and Small Drilling-Machines in Development-Work, by Frederick T. Williams, Victor, Colo.

A Reference-Scheme for Mine-Workings, by Wilbur E. Sanders, Helena, Mont.

Cost Accounts of Gold-Mining Operations, by T. H. Sheldon, Victor, Colo.

Screens for Sizing, by Ernest A. Hersam, Berkeley, Cal.

Notes on Southern Nevada and Inyo County, California, by Harry H. Taft, Denver, Colo.

The Geology and Petrography of the Goldfield Mining-District, Nevada, by John B. Hastings, Colo., and Charles P. Berkey, New York City.

The Mojave Mining-District, California, by Charles E. Bateson, New York City.

Discussion of the paper of James Gayley, on "The Application of Dry-Air Blast to the Manufacture of Iron," by Edward D. Campbell, Ann Arbor, Mich.

Discussion of the paper of H. R. Hall, on "The Use of High Percentages of Fine Ore in a Charcoal Blast-Furnace,"[*] by R. H. Sweetser, Sault Ste. Marie, Ontario, Can.

Discussion of the paper of F. L. Grammer, on "Flue-Dirt and Top-Pressure in Iron Blast-Furnaces; a Study of the Influences Controlling Them," by Thomas F. Witherbee, Durango, Mex.

Discussion of the paper of J. E. Johnson, Jr., on "The Physical Action of the Blast-Furnace," by Thomas F. Witherbee, Durango, Mex.

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[*] *Trans.*, xxxvi., p. 835.

Discussion of the paper of H. H. Campbell, on "The Influence of Carbon, Phosphorus, Manganese and Sulphur on the Tensile Strength of Open-Hearth Steel," by Mansfield Merriman, South Bethlehem, Pa.

Discussion of the paper of Jüptner von Jonstorff and others on "Comparison of Methods for the Determination of Carbon and Phosphorus in Steel," by Clemens C. Jones, Richmond, Va., and R. W. Raymond, New York City.*

Discussion of the paper of James P. Roe, on "The Manufacture and Characteristics of Wrought-Iron," by Taylor Allderdice, Pittsburg, Pa.†

Discussion of the paper of M. R. Campbell, on "The Commercial Value of Coal-Mine Sampling,‡ by A. Bement, Chicago, Ill.

Discussion of the paper of M. R. Campbell, on "The Classification of Coals,"§ by Dr. Persifor Frazer, Philadelphia, Pa.

Reply to Mr. Rose's Discussion of the paper by Hofman and Magnuson, on "The Effect of Silver on the Chlorination and Bromination of Gold," by H. O. Hofman, Boston, Mass.||

Discussion of the paper of Messrs. Gibb and Philp, on "The Constitution of Mattes Produced in Copper Smelting,"¶ by Edward Keller, Baltimore, Md.

The following papers were read by title, for future publication:

Gold-Dredging in the Urals, with Notes on Dredging in Siberia, by William H. Shockley, New York City.

The Roumanian Oil-Field, by P. Charteris A. Stewart, Cairo, Egypt.

ENTERTAINMENTS AND EXCURSIONS.

Besides the enjoyable informal reunion of the first evening, on invitation of the faculty and officers of Lehigh University, on the evening of February 22, the visiting members of the Institute and their accompanying guests were received more elaborately in the old Sun Inn of Bethlehem, by the University and the citizens and manufacturing establishments of the Bethlehems. The whole house was thrown open, the reception being held on the third floor, and refreshments served on the second floor; the dancing began at 10 o'clock. The entire evening was most delightful, The ladies representing the hosts were: Mrs. Robert H. Sayre, Mrs. Henry S. Drinker, Mrs. E. M. McIlvain, Mrs. A. B. de Saulles, Mrs. John Fritz, Mrs. G. B. Linderman, Mrs. Charles M. Dodson, Mrs. A. B. Fichter, and Mrs. William B. Myers.

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* *Trans.*, xxxvi., 741. † *Trans.*, xxxvi., 823. ‡ *Trans.*, xxxvi., 834.

§ *Trans.*, xxxvi., 825. || *Trans.*, xxxvi., 802. ¶ *Trans.*, xxxvi., 837.

On Friday morning, February 23, began the excursions, hospitably provided for by the railroad companies and the industrial establishments of the vicinity. On a special train, put at their service by the New Jersey Central railroad, the members and guests proceeded to Palmerton, near Hazard, for inspection of the extensive new works of the New Jersey Zinc Works, comprising the largest zinc oxide plant in the world, admirably equipped with a spelter-plant and spiegel-furnace.

This company has other works and mines in various parts of the country—at Newark, N. J., South Bethlehem, Pa., Mineral Point, Wis., Waukegan (North Chicago), Gas City and Iola, Kans., Cañon City, Colo., DePue, Ill., Florence, Pa., etc.; but the Palmerton or Hazard works, treating ores from the Franklin Furnace mine of New Jersey, located in the heart of the anthracite region, substantially built, with a splendid equipment, is not only doing great work but preparing for greater. Besides the zinc oxide department, with its building one-third of a mile long, its hundreds of furnaces, and its production of 250,000 lb. of oxide every 24 hours, the spelter department, of modern design and construction, producing spelter of unusual purity (from 99.85 to 99.95 per cent. of zinc) for use in finest castings, galvanizing, and processes requiring special qualities of tenacity and ductility, and laid out upon a scale providing for great extension, there is also a plant for making sulphuric acid (5 tons of 66° acid per day), and a lithophon plant for producing that white enamel pigment. Electric motors and numberless other time- and labor-saving appliances abound on every hand, replacing manual labor by ingenious machines and devices to a very notable extent, all driven by an ample power-plant. Major de Saulles, Mr. Stone, Mr. Queneau and other engineers of the company guided the visitors through the works.

In the afternoon the party went by the special train to the Atlas Portland Cement Co.'s works at Northampton, in the great power-house of which, elaborately decorated with architectural structures, statues, medallions and emblems in cement, luncheon was served. The party was afterwards guided through the kiln-buildings, packing-houses, storage-houses, boiler- and power-houses, etc., which cover an immense area. This visit was followed by a similar inspection, under courteous conductors, of the works of the Lehigh Valley Portland Cement Co., where there was opportunity to note the differences of operation in these two vast establishments for cement-making, and to admire the ingenuity and skill shown in all the methods for manufacturing this indispensable material in the modern modes of construction.

On the return, the party stopped at the works of the Thomas Iron Co. at Hokendauqua, finding special interest in the new (1905) blowing-engines, of the Allis-Chambers cross-compound type, which, at 54 revolutions, supply 41,563 cu. ft. of air per min.; and the new turbine pumping-plant, driven by electric power.

The visitors received souvenirs of the trip,—from the Atlas Cement Co., a diary; from the Lehigh Cement Co., a metal match-box and pen- and pencil-holder, and from the Thomas Iron Co., a paper-weight in the shape of a comfortable looking little pig, facetiously called a "Thomas pig." David Thomas, the founder of the Thomas Iron Co., was elected first president of the Institute at the first meeting in May, 1871, at Wilkes-Barre, and was for many years an honorary member.

The day was concluded by a pleasant reunion at the Northampton Club, South Bethlehem, in the evening.

On Saturday, February 24, the party went on a special train, provided by the courtesy of the Lehigh Valley railroad, to the notable foundry- and machine-shops of the Ingersoll-Rand Co., near Phillipsburg, N. J. Here, led by many kindly guides through the offices, drafting-rooms, shops, power-houses, warehouses, etc., the visitors saw the wonderful processes of manufacturing some of the most potent implements of modern constructive work,—air-compressors for driving the appliances, and the instruments themselves, rock-drills, riveting-hammers, stone-working tools, coal-cutters, pumps, etc., many of which were of additional interest from being seen in operation. Among these, the novel Temple-Ingersoll electric-air rock-drill, just put on the market, attracted the greatest attention.

With its 200 acres of land in the shop-grounds, 481,661 sq. ft. of floor-space in buildings, a foundry-capacity of 150 tons per day, with electric and locomotive cranes, railway-track, cars and locomotives, with a great steam and electric power-plant and all manner of labor-saving devices, this latest and best of the establishments of the Ingersoll-Rand Co. was a sight to be remembered.

During the past 25 years, this company and its predecessors have put forth air-compressors of an aggregate of 750,000 h.p., 7,000 rock-drills, 5,200 coal-cutters, 7,500 pneumatic tools, etc.

A delightful dinner in the company's private dining-rooms closed this visit of inspection, at which, with Major de Saulles as toast-master, a number of apt and witty speeches gave expression to the general sense of friendly good-humor that pervaded the gathering. A photograph of the group of more than a hundred ladies and gentlemen of the party was taken, by procurement of the Company, in front of one of the Ingersoll-Rand buildings.

Some of the party departed to their homes from this point; but the majority returned to South Bethlehem and visited the works of the New Jersey Zinc Co. in that place, rounding out the proceedings of the ninetieth meeting of the Institute, which had been full of varied interest and satisfaction.

The following list, which in all probability does not contain the names of all who attended the sessions, is composed of the names of members and guests registered at the headquarters.

E. O. C. Acker,	Bethlehem, Pa.
William Afflich,	Ellsworth, Pa.
Edgar A. Ashcroft,	London, England.
W. S. Ayres,	Hazleton, Pa.
Mrs. W. S. Ayres,	Hazleton, Pa.
F. E. Bachman,	Port Henry, N. Y.
Mrs. F. E. Bachman,	Port Henry, N. Y.
H. Foster Bain,	Urbana, Ill.
David Baker,	Philadelphia, Pa.
Robert M. Bird,	South Bethlehem, Pa.
Cyrus Borgner,	Philadelphia, Pa.
Mrs. Cyrus Borgner,	Philadelphia, Pa.
Miss Borgner,	Philadelphia, Pa.
Horace Boyd,	Hokendauqua, Pa.
John Boyer,	Bethlehem, Pa.
Albert Brodhead,	Bethlehem, Pa.
Robert E. Brooke,	Birdsboro, Pa.
Otto C. Burkhart,	Bethlehem, Pa.
R. C. Carpenter,	Ithaca, N. Y.
Charles Catlett,	Staunton, Va.
S. H. Chauvenet,	Sheridan, Pa.
S. P. Christie,	High Bridge, N. J.
Mrs. S. P. Christie,	High Bridge, N. J.
William H. Chandler,	South Bethlehem, Pa.
E. T. Clymer,	Philadelphia, Pa.
F. H. Clymer,	Reading, Pa.

L. S. Clymer,	Riegelsville, Pa.
Mrs. L. S. Clymer,	Riegelsville, Pa.
W. B. Cogswell,	Syracuse, N. Y.
Mrs. W. B. Cogswell,	Syracuse, N. Y.
Frederick Conlin,	Bethlehem, Pa.
George G. Converse,	South Bethlehem, Pa.
Edgar S. Cook,	Pottstown, Pa.
Mrs. Edgar S. Cook,	Pottstown, Pa.
C. B. Cook,	Pottstown, Pa.
Edward B. Cook,	Pottstown, Pa.
M. B. Cutter,	Bethlehem, Pa.
Daniel Davis,	Alburtis, Pa.
Arthur B. de Saulles,	South Bethlehem, Pa.
Mrs. Arthur B. de Saulles,	South Bethlehem, Pa.
Mrs. C. M. de Saulles,	South Bethlehem, Pa.
John H. De Saulles,	New York, N. Y.
W. A. Doble,	San Francisco, Cal.
Charles M. Dodson,	Bethlehem, Pa.
P. J. Donohue,	Salt Lake City, Utah.
B. I. Drake,	New York, N. Y.
Henry S. Drinker,	South Bethlehem, Pa.
Howard W. DuBois,	Philadelphia, Pa.
Mrs. Howard W. DuBois,	Philadelphia, Pa.
Howard Eckfeldt,	South Bethlehem, Pa.
Mrs. Howard Eckfeldt,	South Bethlehem, Pa.
George R. Elder,	Ellsworth, Pa.
Lincoln Ellsworth,	Bethlehem, Pa.
William Esty,	Montclair, N. J.
Ernst F. Eurich,	Bethlehem, Pa.
Harold G. Eynon,	Philadelphia, Pa.
Thomas M. Eynon,	Philadelphia, Pa.
B. F. Fackenthal, Jr.,	Riegelsville, Pa.
Mrs. B. F. Fackenthal, Jr.,	Riegelsville, Pa.
A. B. Fichter,	Bethlehem, Pa.
Frank Firmstone,	Easton, Pa.
W. S. Franklin,	Bethlehem, Pa.
John Fritz,	Bethlehem, Pa.
J. W. Fuller, Jr.,	Catasauqua, Pa.
Mrs. J. W. Fuller, Jr.,	Catasauqua, Pa.
E. W. Furst,	Cleveland, O.
James Gayley,	New York, N. Y.
Fritz Glein,	Portoferraio, Italy.
G. McM. Godley,	New York, N. Y.
H. H. Godshall,	Lonsdale, Pa.
Charles Goodman,	New York, N. Y.
R. W. Gordon,	Rhyolite, Nev.
Charles B. Green,	Easton, Pa.
Frank Haas,	Fairmount, W. Va.
N. V. Hansell,	Lyon Mt., N. Y.
F. E. Haverstick,	Philadelphia, Pa.
C. W. Hayes,	Washington, D. C.
Homer W. Hendricks,	Bethlehem, Pa.

Henry H. Hendshaw,	Albany, N. Y.
H. V. Hesse,	Fairmount, W. Va.
L. Holbrook,	New York, N. Y.
Mrs. L. Holbrook,	New York, N. Y.
J. H. Holderness,	South Bethlehem, Pa.
Garret L. Hoppes,	Bethlehem, Pa.
Henry M. Howe,	New York, N. Y.
G. A. Howells,	New York, N. Y.
Charles E. Hulick,	Hellertown, Pa.
C. S. Hurd,	New York, N. Y.
Edward S. Hutchinson,	Newtown, Pa.
Mrs. Edward S. Hutchinson,	Newtown, Pa.
Walter R. Ingalls,	New York, N. Y.
John D. Irving,	South Bethlehem, Pa.
Woolsey McA. Johnson,	Iola, Kan.
Archibald Johnston,	Bethlehem, Pa.
W. J. Johnston,	New York, N. Y.
Mrs. W. J. Johnston,	New York, N. Y.
J. H. Jowett,	New York, N. Y.
Edward K. Judd,	New York, N. Y.
James F. Kemp,	New York, N. Y.
J. S. Kennedy,	Stanhope, N. J.
Paul S. King,	New York, N. Y.
Charles Kirchhoff,	New York, N. Y.
Joseph F. Klein,	Bethlehem, Pa.
I. N. Knapp,	Philadelphia, Pa.
S. F. Knapp,	Cleveland, O.
Walter S. Landis,	Bethlehem, Pa.
T. Harry Lee,	Baltimore, Md.
Mrs. T. Harry Lee,	Baltimore, Md.
N. Lilienberg,	Philadelphia, Pa.
Garrett B. Linderman,	South Bethlehem, Pa.
Stuart Lindesley,	Orange, N. J.
Mrs. Stuart Lindesley,	Orange, N. J.
C. P. Linville,	State College, Pa.
L. P. Löhne,	Cleveland, O.
E. J. McCausland,	Ithaca, N. Y.
E. M. McIlvain,	South Bethlehem, Pa.
Mrs. E. M. McIlvain,	South Bethlehem, Pa.
William R. McIlvain,	Reading, Pa.
Mrs. William R. McIlvain,	Reading, Pa.
Henry Maddock,	Bethlehem, Pa.
Charles A. Matcham,	Allentown, Pa.
Mrs. Charles A. Matcham,	Allentown, Pa.
Miss C. Matcham,	Allentown, Pa.
Mr. Sidney H. Matcham,	Allentown, Pa.
C. A. Meissner,	New York, N. Y.
Mansfield Merriman,	South Bethlehem, Pa.
Harlan C. Miner,	Gloucester, N. J.
N. B. Mitman,	Philadelphia, Pa.
H. S. Munroe,	New York, N. Y.
R. V. Norris,	Wilkes-Barre, Pa.

C. L. O'Neil,	Allentown, Pa.
George Ormrod,	Allentown, Pa.
Mrs. George Ormrod,	Allentown, Pa.
Miss Ormrod,	Allentown, Pa.
I. P. Pardee,	Hazleton, Pa.
Mrs. I. P. Pardee,	Hazleton, Pa.
E. W. Parker,	Washington, D. C.
G. S. Patterson,	Vivian, W. Va.
Mrs. G. S. Patterson,	Vivian, W. Va.
Edmund C. Pechin,	Buchanan, Va.
Joseph S. Pendleton,	Reading, Pa.
George Pettinos,	Bethlehem, Pa.
A. L. J. Queneau,	South Bethlehem, Pa.
Rossiter W. Raymond,	New York, N. Y.
Thomas T. Read,	New York, N. Y.
J. W. Reno,	New York, N. Y.
Robert Ridgway,	New York, N. Y.
Thomas Robins, Jr.,	New York, N. Y.
Mrs. Thomas Robins, Jr.,	New York, N. Y.
M. K. Rodgers,	Seattle, Wash.
C. W. Roepper,	Boston, Mass.
E. F. Rotber,	New York, N. Y.
Joseph W. Richards,	Bethlehem, Pa.
Mrs. Joseph W. Richards,	Bethlehem, Pa.
Robert H. Richards,	Boston, Mass.
James F. Sanborn,	New York, N. Y.
John F. Saeger,	Allentown, Pa.
Mrs. John F. Saeger,	Allentown, Pa.
Robert H. Sayre,	South Bethlehem, Pa.
Harry J. Seaman,	Catasauqua, Pa.
Mrs. Harry J. Seaman,	Catasauqua, Pa.
Edward Schroeder,	New York, N. Y.
Abr. S. Schropp,	Bethlehem, Pa.
J. M. Sherrerd,	Easton, Pa.
Mrs. J. M. Sherrerd,	Easton, Pa.
F. F. Sharpless,	New York, N. Y.
Porter W. Shimer,	Easton, Pa.
E. M. Shipps,	Newburgh, N. Y.
L. Bennett Smith,	Wilkesbarre, Pa.
Oberlin Smith,	Bridgeton, N. J.
Mrs. Oberlin Smith,	Bridgeton, N. J.
Miss Smith,	Bridgeton, N. J.
Baird Snyder, Jr.,	Lansford, Pa.
Harrison Souder,	Cornwall, Pa.
Arthur C. Spencer,	Washington, D. C.
Morton Stevens,	Philadelphia, Pa.
Joseph Struthers,	New York, N. Y.
H. H. Stoek,	Scranton, Pa.
L. S. Sullivan,	Bethlehem, Pa.
Knox Taylor,	Plainfield, N. J.
Mrs. Knox Taylor,	Plainfield, N. J.
L. H. Taylor, Jr.,	Philadelphia, Pa.

John W. Thomas, ... Island Park, Pa.
J. B. Tyrrell, ... Dawson, Y. T., Can.
Leonard Waldo, ... Plainfield, N. J.
R. S. Weaver, ... Catasauqua, Pa.
Walter Harvey Weed, ... Washington, D. C.
Mrs. Walter Harvey Weed, ... Washington, D. C.
Olaf Wenstrom, ... Boston, Mass.
Maunsel White, ... Bethlehem, Pa.
Mrs. Thomas D. Whitaker, ... Allentown, Pa.
W. B. Whitmam, ... Philadelphia, Pa.
E. P. Wilbur, ... South Bethlehem, Pa.
W. A. Wilbur, ... South Bethlehem, Pa.
Eldridge Wilbur, ... South Bethlehem, Pa.
John F. Wilcox, ... Orange, N. J.
William S. Wintersteen, ... Bethlehem, Pa.
Charles Ziegenfuss, ... Bethlehem, Pa.

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